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IDENTIFIERS	Crosswalks (Linking); *Electrical Wiring

ABSTRACT

Commercial and Industrial Wiring, third in a series of three wiring publications, includes the additional technical knowledge and applications required for job entry in the commercial and industrial wiring trade. Instructional materials include a teacher edition, student guide, and two student workbooks. The teacher edition begins with introductory pages, including a training and competency profile, duty-task crosswalk, instructional/task analysis, basic skills icons and classifications, basic skills matrix, and a tools, equipment, and materials list. Each of 16 units consists of some or all of these components: suggested activities (instructional plan, teaching suggestions, references used in unit development, suggested supplemental resources); assignment sheet answer keys; written test; test key; teacher supplements; and transparency masters. The student guide provides some or all of these for each unit: learning activities sheet; objective sheet; information sheet; and student supplements. The student workbook contains these pen-and-paper exercises and skill tests necessary for student mastery of the course: focus assignment (provides students with an opportunity to explore topics presented in a unit and practice their reading, language skills, and critical thinking skills); assignment sheets; and job sheets. The 16 units are blueprint reading and load calculations; tools and equipment; service; transformers; rough-in; lighting; motors and controllers; electrical diagrams and symbols; 2- and 3-wire controls; separate control circuits; sequence controls; jogging controls; reversing starters; special control circuits; programmable logic controllers; and projects (special supplement). (YLB)

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ED 469 907

Commercial and Industrial Wiring, Fourth Edition

Teacher Edition
[and]
Student Guide
[and]
Student Workbook 1
[and]
Student Workbook 2

MAVCC

References 2002
National Electrical Code

02-015643 CN801401
02-015643 CN801402
02-015643 CN801442
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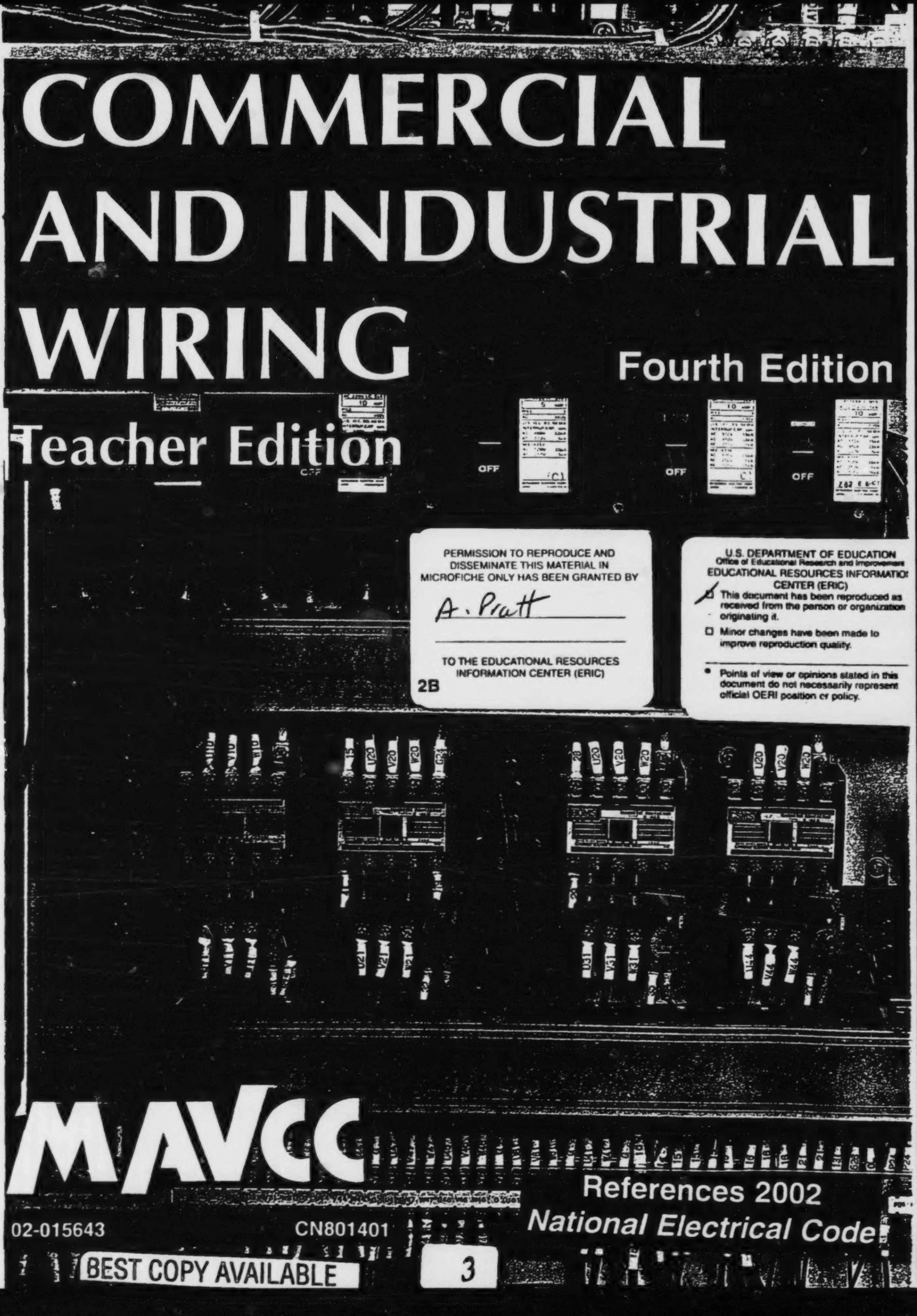

COMMERCIAL AND INDUSTRIAL WIRING

Fourth Edition

Teacher Edition

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Commercial and Industrial Wiring

Fourth Edition

Teacher Edition

Written by

Stan Kaltwasser
Gary Flowers

Revised by

Dan Ipock

Project coordinated by

Glenn Fleming

Developed by

The Multistate Academic and Vocational Curriculum Consortium, Inc.

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Stillwater, OK 74074-4364

For more information, contact the
Multistate Academic and Vocational Curriculum Consortium
1500 West Seventh Avenue
Stillwater, OK 74074-4364

E-mail: mavcc@mavcc.com
Internet: http://www.mavcc.org
Phone: (800)654-3988 or (405)743-5578

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Units of Instruction

Unit 1: Blueprint Reading and Load Calculations

Unit 2: Tools and Equipment

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Unit 4: Transformers

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Unit 6: Lighting

Unit 7: Motors and Controllers

Unit 8: Electrical Diagrams and Symbols

Unit 9: Two- and Three-Wire Controls

Unit 10: Separate Control Circuits

Unit 11: Sequence Controls

Unit 12: Jogging Controls

Unit 13: Reversing Starters

Unit 14 Special Control Circuits

Unit 15: Programmable Logic Controllers

Unit 16: Projects (Special Supplement)

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Corrections

Publication Title ____________________

Page Number	Correction
________	____________________
________	____________________
________	____________________
________	____________________
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Suggestions

- Product Needs (supplemental resources, additional publications, etc.)

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- Other Ideas

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Benefits of Student Editions

- **Save money** by purchasing 6 or more copies (up to 42% off of the single copy price).
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- **Ensure sequential learning** by using MAVCC's unique format that moves the student from simple to complex objectives.
- **Save time** by using this complete, ready-to-teach instructional source.

Key Components of Student Editions

Student Guides	Student Workbooks
◊ Learning Activities Sheet	◊ Focus Assignments
◊ Objective Sheet	◊ Assignment Sheets
◊ Information Sheet	◊ Job Sheets
◊ Student Supplements	

For more information about these components, please refer to the "Use of This Publication" section found in the front of your teacher edition

Contact MAVCC now to purchase your student editions:

• Phone	1-800-654-3988
• E-mail	mavcc@mavcc.com
• Online catalog	www.mavcc.com

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Foreword

Commercial and Industrial Wiring is the third in a series of three wiring publications and includes the additional technical knowledge and applications required for job entry in the commercial and industrial wiring trade.

Basic Wiring, the first publication in the series, serves as the foundation for students enrolled in a wiring program. It is a prerequisite to either *Commercial and Industrial Wiring* or *Residential Wiring*. This series should provide the flexibility that instructors need to meet the individual needs of their students and the community.

Residential Wiring, the second publication in the series, picks up where Basic Wiring ends and prepares the student for entry-level employment in the residential wiring trade. New units on low voltage wiring and home automation have been added in the third edition of this publication.

This edition of *Commercial and Residential Wiring* includes a student workbook that contains focus assignments, assignment sheets, and job sheets. Student workbooks can be purchased individually each year to provide new students with the focus, assignment, and job sheets needed to master the course.

MAVCC's wiring series was developed with the assistance of many individuals who have expertise in various areas of the wiring trade. Some of these individuals represent professional associations and industry. Their assistance and support is greatly appreciated. It should be emphasized that the student needs to be aware of professional trade associations and take an active part in them as much as possible. The professional trade associations, as well as vocational education, are an excellent avenue for continuing education within the electrical trade.

These instructional materials are designed not only for student use but also to assist the teacher in improving instruction. Every effort has been made to make these materials basic, readable, and usable. Teachers will need to develop instructional strategies for localizing, individualizing, and supplementing these materials.

As you use these instructional materials, we hope you will find they contribute to the quality of your program. If any problems occur or if you have suggestions for improvement, please call or write us.

Kimberly Sadler, Chair
Board of Directors
Multistate Academic and
Vocational Curriculum
Consortium

Jane Huston
Executive Director
Multistate Academic and
Vocational Curriculum
Consortium

Acknowledgments

Appreciation is extended to those individuals who contributed their time and talent to the development of *Residential Wiring*.

The contents of this publication were initially planned and reviewed by the following committee members:

Loren Amerine	Hoisington, Kansas
Bill Barnes	Littleton, Colorado
Harold Brown	Hope, Arkansas
Daniel Frohberg	Norfolk, Nebraska
Tracy Naas	Kloten, North Dakota
Mike Pedersen	Sheldon, Iowa
Clifford Schaefer	Ft. Worth, Texas
Randy Wilson	Stillwater, Oklahoma

Review of this publication was completed by selected instructors in the Oklahoma Department of Career and Technology Education system.

A special thank you goes to the following for granting MAVCC permission to reprint certain graphic materials that enhance this text: Telemecanique, Inc.; Hunzicker Brothers; Tel-A-Train Inc.; Advance Transformer Company; Square D Company; and Cutler-Hammer.

Special thanks are also extended to Rick Lomenick, electronic publishing technician, for his hard work, accuracy, and determination in completing revisions and re-formatting this edition.

Appreciation is extended to employees of the Graphics Division of the Oklahoma Department of Career and Technology Education for artwork and printing of this text.

Use of This Publication

Commercial and Industrial Wiring is available in both a teacher and student edition. The contents of these materials are tied to measurable and observable learning outcomes that were identified and validated by the electrical wiring advisory committee, comprised of business/industry representatives and teachers. Competencies align with the Oklahoma Electrical Trades duty/task list, Commercial and Industrial Electricians Assistant, developed by the Oklahoma Department of Career and Technology Education.

Teacher Edition

The complete teacher edition consists of introductory pages, teacher pages, and the student edition. Materials are loose-leaf and three-hole punched and are divided into units of instruction that may be broken into more than one lesson or class period. For added flexibility, each unit is individually numbered beginning with a T for teacher page, followed by the unit number and page number.

Example:

Page 17 of Unit 3 in the teacher pages are represented as T 3–17.

MAVCC—*Commercial and Industrial Wiring* T 3–17

Page 1 of the studentworkbook are sequentially numbered beginning with page 1..

MAVCC *Commercial and Industrial Wiring* Page 1

Pages in the student edition are numbered beginning with the unit number, followed by the page number.

Example:

Page 7 of Unit 5 in the student edition is represented as Page 5–7.

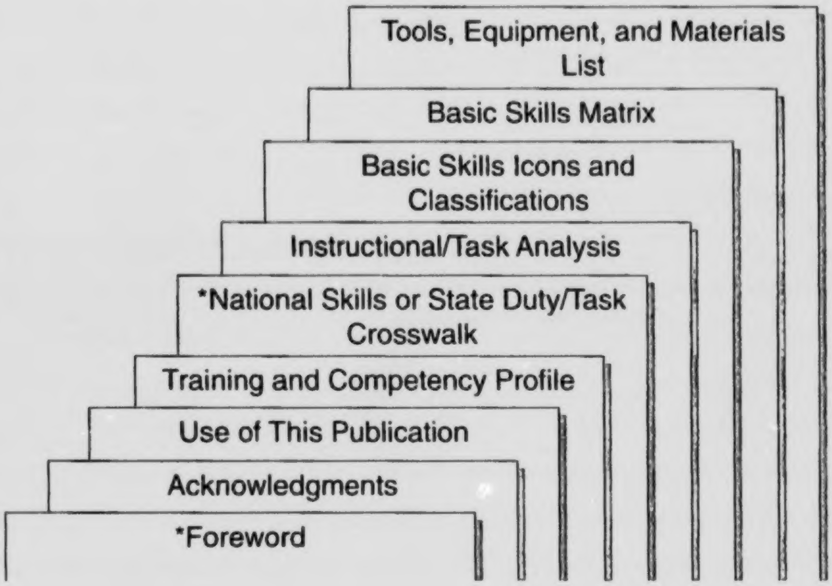
MAVCC—*Commercial and Industrial Wiring* Page 5–7

For group instruction, the teacher should determine the best way to teach each objective and allow for student participation. For self-paced or individualized instruction, students should be provided with opportunities to become involved in planning and being responsible for their own education. Careful study of each unit of instruction by the teacher will help to determine the following:

- amount of material that can be covered in each class period;
- supplies and materials required for assignment sheets and job sheets;
- resource people who must be contacted;
- supplementary materials to be ordered;
- skills that must be demonstrated and the amount of class time needed for demonstrations; and
- amount of class time needed for student practice and return demonstrations of mastered skills.

Teachers are encouraged to localize and personalize these materials to meet the needs of individual students, the community, and prospective employers.

Introductory Pages


Tools, Equipment, and Materials List
Basic Skills Matrix
Basic Skills Icons and Classifications
Instructional/Task Analysis
*National Skills or State Duty/Task Crosswalk
Training and Competency Profile
Use of This Publication
Acknowledgments
*Foreword

Use of This Publication

In addition to general information, such as the table of contents, acknowledgments, and the use of this publication, the following tools have been provided to assist administrators and teachers in planning for instruction.

☐ **Training and Competency Profile.** This form may be copied and used to record information about each student, such as enrollment dates, class attendance, and work experience, and to document the student's mastery of specific job competencies. It can also be used to provide information about the student's qualifications to potential employers and/or for entry into advanced training programs.

☐ **Duty/Task Crosswalk.** This document identifies the state skill standards covered in this publication and lists specifically where these skills are located by unit number and objective.

☐ **Instructional/Task Analysis.** This document provides a quick review of the contents of this publication by identifying the cognitive skills (what the student should know) and psychomotor skills (what the student should be able to do) addressed in each unit of instruction.

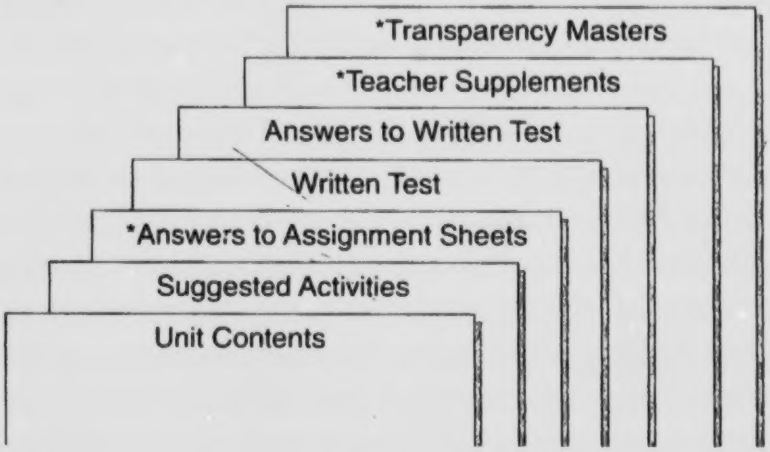
☐ **Basic Skills Icons and Classifications.** This page provides a reference guide of the graphic symbols that are used to identify the basic academic and workplace skills included in each focus assignment, assignment sheet, and job sheet.

☐ **Basic Skills Matrix.** This document graphically summarizes the academic and workplace skills training included in the instructional materials, unit by unit. It should be helpful to teachers in planning for instruction, and to administrators as documentation that basic skills are being taught as part of the vocational training.

☐ **Tools, Equipment, and Materials List.** This document provides a comprehensive list of those items needed in a vocational program for students to complete training. It also can assist administrators and teachers in determining program costs.

Use of This Publication

Teacher Pages



*Designates components that may not appear in every unit of instruction

Teachers should study the teacher and student pages before introducing the unit, allowing enough time to obtain supplemental materials and to contact outside resource persons.

☐ **Suggested Activities.** This component assists teachers during the preparation stage of the teaching/learning process by providing an instructional plan, teaching suggestions, a list of references used in the development of each unit, and a list of suggested supplemental resources (books, posters, pamphlets, videotapes, computer software, and Internet sites) that may be used to enhance instruction.

Instructions for evaluating student performance on the assignment sheets and job sheets are also included in the suggested activities section. Teachers should select and discuss with students the rating scale that will be used.

☐ **Answers to Assignment Sheets.** An answer key is provided, when applicable, to assist the teacher in evaluating student performance on a given assignment.

☐ **Written Test.** This component provides criterion-referenced evaluation of every cognitive objective listed in the unit of instruction, and serves as both a pretest and posttest to assist teachers in measuring each student's competency gains. (Assignment sheet and job sheet objectives are not evaluated on the written test.) If the teacher has added, deleted, or modified any objectives, appropriate changes should be made to both the test and answers to the written test.

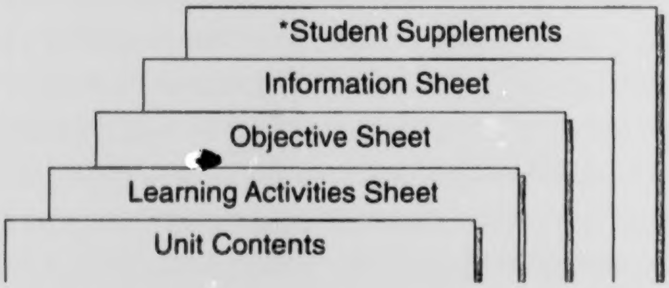
Tests may be divided into shorter tests covering three or four objectives at a time and given soon after those objectives have been covered. A selection of test items from the units covered may be used for a final test at the end of each term if desired. The written test is included in the teacher edition only and should be duplicated for student use.

☐ **Answers to Written Test.** An answer key is provided to assist the teacher in evaluating student performance on the written test.

☐ **Teacher Supplements.** These are optional materials for the teacher to use. They have three purposes: to provide the teacher with higher-level materials to stretch the advanced student; with remedial information or practice to assist the less-advanced student; and with state-of-the-art information in which the teacher may not have a background or with information that is not readily available in other books. Some teacher supplements may be duplicated for student use and are marked accordingly.

☐ **Transparency Masters.** These overheads are used to direct the students' attention to the topic of classroom discussion. Transparencies allow the student to see as well as hear the information being presented, thus reinforcing the learning process. They may provide illustrations, charts, schematics, or additional information needed to clarify and reinforce objectives included in the unit of instruction. Some of these items may also appear with the appropriate objectives in the information sheet in the student edition. The teacher may make acetate copies from the masters or, in most cases, complete transparency sets are available for purchase.

Student Guide



*Designates components that may not appear in every unit of instruction

For best results, students should be provided with a copy of the student edition and should be allowed to take notes in the margins as additional information is provided by the instructor or as the student acquires additional information through library or Internet research.

Use of This Publication

☐ **Learning Activities Sheet.** This component provides a model for teachers to use in implementing a self-paced or individualized program, and guides the student through the required components in the student edition (objective sheet, information sheet, student supplements, assignment sheets, and job sheets). The teacher should modify the learning steps as needed to incorporate resources available in the classroom (videotapes, computer software, magazines, etc.) and to address instructional strategies that may be needed to enhance learning for each student. Final copies should be distributed for student use.

The following icons will be used on the learning activities sheet to denote steps that require additional resources:

📖 Read a book, magazine, journal article, or objectives

🖥 Use a CBT program or other software application

WWW Access a site on the World Wide Web

🖥 Look at PowerPoint® or other computer presentation

📼 Watch a videotape

☐ **Objective Sheet.** This component summarizes each unit for the student and teacher. The objective sheet is based on established performance objectives that state the goals for successful completion of a unit of instruction. Objectives are stated in two forms: unit objectives that state the expected performance of each student after completion of the unit and specific (enabling) objectives that state what the student must be able to do to reach the unit objective.

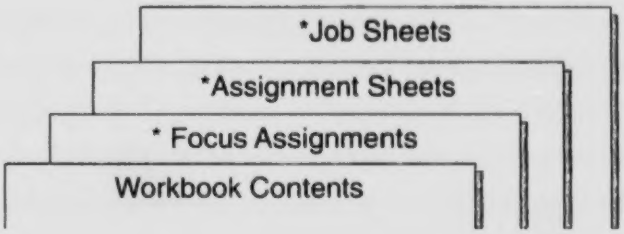
The objectives should be stressed throughout the teaching/learning process. This will help answer any questions concerning performance requirements for each instructional unit. The objectives can also help determine teaching strategies and instructional methods.

Teachers should modify, delete, or add objectives in order to meet the needs of the students and community. When objectives are added, the teacher should remember to supply the needed information, assignment and/or job sheets, and criterion-referenced test items to cover the new objectives.

☐ **Information Sheet.** This component provides the student with the essential information for meeting the cognitive objectives in the unit. Teachers will find that the information sheet serves as an excellent guide for presenting background knowledge necessary to develop the skills specified in the unit objective. Students should read the information sheet before the information is discussed in class. Space is provided in the margins for students and teachers to add notes that clarify and/or expand upon the information presented.

☐ **Student Supplements.** This component is included in a unit of instruction when additional information is needed in order for students to complete one or more of the assignment and/or job sheets. Students are not directly tested over the information presented in a supplement; however, their ability to apply this information may be evaluated in the completion of assignment and/or job sheets.

Student Workbook



*Designates components that may not appear in every unit of instruction.

The student workbook is an integral part of the student materials and should be provided to each student. It contains the pen-and-paper exercises and skill tests necessary for student mastery of the course.

☐ **Focus Assignment.** This activity provides students with an opportunity to explore topics presented in a specific unit of instruction, and gives them an opportunity to practice their reading, language skills including writing and speaking, and critical-thinking skills.

☐ **Assignment Sheets.** The assignment sheets address the learning levels at or above the application level of Bloom's taxonomy. They provide students with an opportunity to use higher-order thinking skills, such as problem solving, synthesizing, analyzing, and evaluating. In addition, they may provide additional opportunities for students to develop their language skills.

Assignment sheets can be paper-and-pencil activities, as well as those using computer software, videotapes, models, handouts, or other resources as appropriate. Criteria are provided to evaluate student performance objectively.

☐ **Job Sheets.** Job sheets are designed as skill tests and give the instructor direction as to the psychomotor skills to be taught, and provide the criteria to evaluate student performance objectively. They also help provide potential employers with a picture of the skills being taught during training and the performances that might be reasonably expected from an individual who has completed the training.

The teacher should provide students with a copy of each job sheet and/or the procedure's manual and/or job specifications when necessary. The teacher should also discuss the equipment and materials that will be needed for the job and the criteria that will be used to evaluate the student's performance, and demonstrate the procedure prior to having students practice the procedure. Safety should be stressed as part of each demonstration.

When a student is ready to be evaluated, the teacher should follow the instructions for evaluating student performance which may be found in the suggested activities component of the teacher unit.

As you use these instructional materials we hope that you will find that they contribute to the quality of your program. If any problems occur or if you have any suggestions for improvement of the materials, please write us at 1500 West Seventh Avenue, Stillwater, OK 74074-4364, or E-mail us at mavcc@mavcc.com.

Training and Competency Profile

Student Information

Program ____________________ Instructor ____________________

Name ____________________ Soc. Sec. No. ____________________

Address ____________________ Phone ____________________

Grade ____________ School ____________________

Allergies/Disabilities that might require special accommodation for training (please specify)

____

In case of emergency, contact ____________________ Phone ____________________

Record of Enrollment

Date of Enrollment ____-____-____ Total Class Hours________ Total Hours Absent________

Date of Withdrawal ____-____-____ Total On-the-Job Training Hours________ Total Hours Tardy________

Date of Completion ____-____-____ Total Lab Hours________

On-the-Job Training/Work Experience

____________________ ____________________
Place of Employment Address

____________________ ____________________
Supervisor's Name Phone

____________________ ____________________
Duration of Employment Job Title

____
Job Responsibilities

____________________ ____________________
Place of Employment Address

____________________ ____________________
Supervisor's Name Phone

____________________ ____________________
Duration of Employment Job Title

____
Job Responsibilities

Training and Competency Profile

Student Evaluation

Directions: Evaluate the student using one of the rating scales below. Write the appropriate number to indicate the degree of competency achieved. The descriptions associated with each of the numbers focuses on a level of student performance for each of the tasks listed. The written test scorelines are provided for optional teacher use. They may not be applicable in all cases.

Sample A

4 **Skilled**—Can perform job with no additional training.
3 **Moderately Skilled**—Has performed job during training program; limited additional training may be required.
2 **Limited Skill**—Has performed job during training program; additional training is required to develop skill.
1 **Unskilled**—Is familiar with process, but is unable to perform job.
0 **No Exposure**—No information or practice provided during training program.

Sample B

Yes—Can perform job with no additional training.
No—Is unable to perform job satisfactorily.

Unit 1: Blueprint Reading and Load Calculations

______ 1. Construct an electric blueprint
______ 2. Perform load calculations and determine overcurrent protection and conductor size
______ 3. Compute lighting loads
______ 4. Derate neutral loads
______ 5. Determine maximum numbers of conductors in conduit
______ 6. Determine wire sizes to prevent voltage drop
______ 7. ______________________________

Written Test Scores
Pretest Score ________%
Posttest Score ________%

Unit 2: Tools and Equipment

______ 1. Bend, cut, ream, and thread one-half-inch rigid metal conduit
______ 2. Bend EMT stub-ups.
______ 3. Make back-to-back bends on one-half-inch EMT
______ 4. Make offset bends on one-half-inch EMT
______ 5. Bend and install one-half-inch EMT.
______ 6. Bend a three-point saddle on one-half-inch EMT.
______ 7. Bend a four-point saddle on one-half-inch EMT
______ 8. Cut, ream, offset, and install connectors on one-half-inch PVC
______ 9. ______________________________

Written Test Scores
Pretest Score ________%
Posttest Score ________%

Unit 3: Service

______ 1. Install an overhead raceway with service entrance conductors to a meter base
______ 2. Connect a meter base assembly to a load center or panel
______ 3. ______________________________

Written Test Scores
Pretest Score ________%
Posttest Score ________%

Unit 4: Transformers

______ 1. Analyze utility company methods for delivering electrical power
______ 2. Draw a three -phase wye-delta transformer
______ 3. Locate and list two exceptions on transformer room construction for dry type transformers
______ 4. Locate and list two exceptions concerning oil-insulated transformers
______ 5. Given amperes, calculate KVA on a three-phase system
______ 6. Test transformer turn ratios
______ 7. Test transformer insulation resistance
______ 8. Connect transformer primary and secondary windings in a delta-wye configuration
______ 9. Test and compare primary apparent power of a transformer to secondary apparent power
______ 10. ______________________________

Written Test Scores
Pretest Score ________%
Posttest Score ________%

Training and Competency Profile

Unit 5: Rough-In

_______ 1. Determine the number of conductors allowed to be added to an existing conduit
_______ 2. Rough in a wood framed wall
_______ 3. Install outlet boxes on steel rods
_______ 4. Install outlet boxes on steel studs using caddy metal stud clips for switch boxes
_______ 5. Install masonry boxes in a block wall
_______ 6. ______________________________

Written Test Scores
Pretest Score _________%
Posttest Score _________%

Unit 6: Lighting

_______ 1. Locate articles in the *NEC* concerning lighting requirements
_______ 2. Change a two-lamp ballast in a fluorescent fixture
_______ 3. Change sockets in a fluorescent fixture
_______ 4. Change an HID ballast
_______ 5. Change a quartz lamp
_______ 6. ______________________________

Written Test Scores
Pretest Score _________%
Posttest Score _________%

Unit 7: Motor and Controllers

_______ 1. Interpret nameplate information
_______ 2. Describe remedies for common motor problems
_______ 3. Use the *National Electrical Code* to answer questions about motor control circuits
_______ 4. Distinguish between motor starters and contactors
_______ 5. Answer questions about uses of contactors and motor starters
_______ 6. Disassemble, inspect, and clean a motor
_______ 7. Identify run, common, and start terminals on hermetically sealed motors
_______ 8. Test capacitors with an ohmmeter
_______ 9. Wire a three-phase motor for dual voltages
_______ 10. Perform maintenance on a magnetic contactor
_______ 11. ______________________________

Written Test Scores
Pretest Score _________%
Posttest Score _________%

Unit 8: Electrical Diagrams and Symbols

_______ 1. Construct a basic ladder diagram
_______ 2. Identify electrical symbols in a wiring diagram
_______ 3. ______________________________

Written Test Scores
Pretest Score _________%
Posttest Score _________%

Unit 9: Two-and Three-Wire Controls

_______ 1. Complete a ladder and wiring diagram of a two-wire control using a thermal switch
_______ 2. Draw a ladder diagram of a three-wire control with an "on" indicating pilot light
_______ 3. Draw a ladder and wiring diagram of a three-wire control with an "off" indicating pilot light
_______ 4. Determine the number and size of conductors needed to operate a two-wire control system
_______ 5. Determine the number and size of conductors needed to operate a three-wire control system
_______ 6. Wire a two-wire control
_______ 7. Wire two float switches to operate a starter (series connection)
_______ 8. Wire two float switches to operate a starter (parallel connections)
_______ 9. Wire a pressure switch to operate a starter with "on" and "off" pilot lights
_______ 10. Wire a three-wire control system
_______ 11. Wire a multiple station three-wire control
_______ 12. Wire a multiple station three-wire control with "on" and "off" pilot lights.
_______ 13. ______________________________

Written Test Scores
Pretest Score _________%
Posttest Score _________%

Unit 10: Separate Control Circuits

_______ 1. Read and interpret ladder diagrams using separate control circuits
_______ 2. Answer questions dealing with control circuits
_______ 3. Determine the size and number of conductors needed to operate a separate control circuit
_______ 4. Wire a relay and a load with a separate control circuit
_______ 5. Wire a three-phase starter to operate by a separate control circuit
_______ 6. ______________________________

Written Test Scores
Pretest Score _________%
Posttest Score _________%

Unit 11: Sequence Control

_______ 1. Answer questions related to a sequence control diagram
_______ 2. Answer questions related to an auxiliary contact interlocking diagram
_______ 3. Wire two starters in sequence
_______ 4. Wire two starters with auxiliary contact interlocking
_______ 5. ______________________________

Written Test Scores
Pretest Score _________%
Posttest Score _________%

Training and Competency Profile

Unit 12: Jogging Controls

________ 1. Convert ladder diagrams to wiring diagrams
________ 2. Determine the number of conductors needed to operate jogging controls
________ 3. Wire a job through a lock-stop push button
________ 4. Wire a job through a two-position selector switch
________ 5. Wire a job through a two-circuit push button
________ 6. Wire a job through a control relay
________ 7. ________________________________

Written Test Scores
Pretest Score ________%
Posttest Score ________%

Unit 13: Reversing Starters

________ 1. Describe the sequence of operation of ladder diagrams
________ 2. Determine the number of conductors needed to operate a reversing control
________ 3. Wire a reversing starter with a three-position selector switch
________ 4. Wire a reversing starter with one control station using auxiliary contact and mechanical interlock
________ 5. Wire a reversing starter with one control station using push button interlock and auxiliary contact interlock
________ 6. Wire a reversing starter with two control stations
________ 7. Wire drum switches
________ 8. Wire a reversing starter with jog in both directions
________ 9. ________________________________

Written Test Scores
Pretest Score ________%
Posttest Score ________%

Unit 14: Special Control Circuits

________ 1. Build a relay control circuit
________ 2. Wire a latching relay or contactor
________ 3. Wire a timed "on" circuit
________ 4. Wire a timed "off" circuit
________ 5. Energize three starters in a timed sequential order
________ 6. De-energize three starters in a timed sequential order
________ 7. Build a ground fault indicator circuit
________ 8. ________________________________

Written Test Scores
Pretest Score ________%
Posttest Score ________%

Unit 15: Programmable Logic Controllers

________ 1. Match I/O devices with their functions
________ 2. Convert between numbering systems
________ 3. ________________________________

Written Test Scores
Pretest Score ________%
Posttest Score ________%

Duty/Task Crosswalk

This duty/task crosswalk is based on the Oklahoma Duty/Task List for the Electrical Trades, Commercial/Industrial Electrical Assistant, and can be used as a cross-reference in other states.

Abbreviations:

FA—Focus Assignment
AS—Assignment Sheet
JS—Job Sheet

Skill Code	Skill Description	Unit #	Specific Reference
E.01	Plan a sequence of work operation	Projects	All
E.03	Compile a list of motor nameplate data	7	AS 1
E.07	Compile list of materials from wiring blueprints	Projects	All
E.10	Draw external power diagrams	8	AS 1
E.11	Draw schematic diagrams from prewired circuits	4/9/10 12/14	AS 1/AS 1-4/JS 1 AS 1/ JS1
E.12	Draw an "as-built" electrical plan	Projects	All
G.08	Test capacitors in an AC circuit	4	JS 4
G.15	Set up and operate for AC circuits	4/7	JS 1-4/JS 2&3
I.03	Calculate individual circuits	1	AS 2
I.05	Calculate service size – branch circuit	Projects	All
I.07	Perform transformer and motor calculations	1/4 Projects	AS 2/AS 1&4, JS 1-4 All
I.08	Calculate voltage drop	Projects	All
I.09	Calculate conductors	1/5/9 10/12/13 Projects	AS 2&4/JS 1/AS 4&5 AS 3/AS 2/AS 2 All
I.11	Calculate over-current protection	1/9 10/12 Projects	AS 2/AS 4&5 AS 3/AS 2 All
J.01	Ground service equipment – grounding electrode system	3	JS 2
J.02	Install main service panels	3	JS 2
J.08	Install temporary service	3	JS 1&2
J.10	Install metering equipment	3	JS 1&2
K.01	Install and size boxes		

Duty/Task Crosswalk

Skill Code	Skill Description	Unit #	Specific Reference
K.03	Install bar-hanger mounted box	5	JS 1-3
K.05	Install flush mount switch and outlet box in		
	– drywall	5	JS 1
	– masonry wall	5	JS 4
K.06	Install gangable boxes	5	JS 1-4
K.07	Install octagon outlet box	5	JS 1
K.08	Install surface mount junction box	5	JS 1
L.01	Lay out electrical systems		
	– use material and devices labeled and listed for the purpose	5/Projects	JS 1/All
	– follow all grounding and bonding requirements	5/Projects	JS 1/All
L.02	Rough-in feeders and circuits using a cable system		
	– new construction	5	JS 1
L.04	Rough-in cables or conduits for branch circuits	5	JS 1
L.05	Connect circuits to circuit breaker panels	5	JS 1
L.06	Rough-in circuits to outlet boxes	5	JS 1
L.08	Rough-in a circuit for an outlet controlled with		
	– feed to the device outlet box	5	JS 1
L.10	Rough-in cables for general purpose branch circuits		
	– three-way switch	Projects	Scenario 3
	– receptacle outlet	5	JS 1
L.14	Rough-in branch circuit wires to panels	5	JS 1
L.15	Install panels and subpanels	Projects	Scenarios 4 & 8
L.17	Rough-in weatherproof outlet boxes and covers	Projects	Scenario 1
L.20	Install conduits, cables, raceways, and equipment		
	– indoor	5/16	JS 1/JS 2 & 3
	– outdoor	Projects	Scenario 1
	– thin wall (EMT)	5	JS 1
	– multi-conductor	5	JS 1
	– wet locations	16	Scenario 1
	– dry locations	5	JS 1-3
	– submerged locations	Projects	Scenario 7
L.21	Install receptacle circuits		
	– single phase	5	JS 1
	– three phase	5	JS 1
M.10	Install/connect for ventilation systems	Projects	Scenario 3
N.11	Connect pump and well pump motors	Projects	Scenario 1
N.12	Install/connect panels	Projects	Scenario 8
N.14	Install/connect low-voltage systems	10	JS 1
N.20	Install smoke and CO detectors	5	JS 3

Skill Code	Skill Description	Unit #	Specific Reference
O.02	Troubleshoot/repair/replace relays and timers	Projects	Scenarios 7 & 8
O.11	Troubleshoot/repair/replace electric motors	7	AS 2 & JS 4
P.08	Install systems in hazardous locations	Projects	Scenarios 2 & 8
P.13	Test the insulation of cables and equipment	4	JS 2
Q.01	Install and connect transformers		
	– step-down	4	JS 1
Q.02	Test transformer for output and performance under load	4	JS 1 & 4
Q.07	Connect three single-phase transformers to form a		
	– delta-delta configuration (3 or 4 wire)	4	JS 3
R.04	Change the direction of rotation of electrical motors	13	JS 1
R.09	Connect three-phase AC motor to run off different voltages	7	JS 4
S.01	Install, troubleshoot, and repair motor control systems		
	– single-phase systems	7	JS 1
	– three-phase systems	7/9/12	JS 4/JS 1-3/JS 1-4
		14/Projects	JS 3-7/All
	– magnetic motor starters	7/11	JS 5/JS 1&2
	– interlocking, reversing systems	13	JS 1-3
	– hand sequence systems	11	AS1, JS 1 & 2
	– timed sequence systems	14	JS 5&6
		Projects	Scenarios 2, 9 & 10
	– jogging systems	12/13	AS 1-4/JS 6
	– multiple station systems		
	• 3 wire-motor control systems	9/14	JS 5-7/JS 7
	– reversing motor control systems		
	• using drum switches	13/Projects	JS 5/Scenario 5
	• using reversing starters	13	JS 4 & 6
		Projects	Scenarios 3 & 8
S.03	Install, troubleshoot and repair special purpose motor control systems		
	– AC reduced voltage starter (resistance)	10	AS 1
	– pilot-motor-driven motor timing controls	9/10	JS 7/AS 1, JS 1
		Projects	Scenario 8
S.05	Install, troubleshoot and repair sensors, controls and relay control systems		
	– control relay systems	10/12/14	JS 1/JS 4/JS 1-4
	– control switches	12/14	JS 1 & 3/JS 1 & 2
		Projects	Scenarios 1, 3 & 6
	– pressure switches	9/Projects	JS 4/Scenario 7
	– time delay relays	10	JS 2
	• on-delay	14/Projects	JS 3/Scenario 9
	• off-delay	14/Projects	JS 4/Scenarios 8 & 10

Skill Code	Skill Description	Unit #	Specific Reference
S.06	Troubleshoot and repair solid state devices in control systems – solid state rectifiers ◦ three phase	10	JS 2
S.08	Install, troubleshoot and repair control wiring for a programmable controller system	10/15	JS 2/AS 1
S. 09	Install control systems using Class 1, Class 2, and Class 3 wiring materials and methods	14	JS 1-4
U.01	Maintain a courteous and responsive attitude toward all customers	All	
U.02	Demonstrate appropriate interpersonal skills	All	
U.03	Maintain self-esteem in self and others	All	
U.04	Recognize the importance of team work and participate as a team member	All	
U.05	Maintain professional respect for co-workers and supervisor	All	
U.06	Demonstrate professionalism	All	
U.07	Practice critical thinking skills to workplace situations	1/Projects	AS 1/All
U.08	Maintain satisfactory attendance	All	
U.10	Function within the organizational structure	All	
U.11	Cooperate with co-workers in the completion of assignments	All	
U.12	Practice self-management (time management) techniques	All	
U.13	Practice deductive and inductive reasoning skills	All	
U.15	Employ listening skills	All	
U.16	Compose written communication legibly using correct grammar, spelling, and format	2	FA
U.17	Demonstrate ability to interpret and follow written directions and information	All	
U.18	Demonstrate ability to interpret and follow oral directions	All	
U.19	Use job-related terminology, symbols, and abbreviations	All	
U.21	Use effective communication techniques	All	
U.22	Use verbal and non-verbal communication techniques	All	
U.23	Apply behavior management techniques to workplace	All	
U.25	Respond to compliments, complaints, conflicts, and criticism appropriately	All	

Skill Code	Skill Description	Unit #	Specific Reference
U.27	Retrieve, recognize, and calculate common statistical formulas		
	– addition, subtraction, multiplication, and division of		
	whole numbers	1	AS 1&2
	decimals	1	AS 1&2
	percentages	1	AS 1&2
U.28	Demonstrate negotiation skills		
	– solve everyday human relations problems	All	
U.29	Demonstrate leadership skills		
	– employ leadership skills	All	

Instructional/Task Analysis

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 1: Blueprint Reading and Load Calculations

1. Terms and definitions
2. Mechanical symbols
3. Plumbing symbols
4. Structural symbols
5. Architectural symbols
6. Electrical symbols
7. Panel, circuit, and other electrical symbols
8. Types of blueprint lines
9. Typical electrical specifications
10. Minimum requirements for electrical devices
11. Determining motor-circuit wire sizes
12. Load calculations
13. Voltage drop
14. Types of blueprints
15. Select participants and describe their functions at a construction site
16. Construct an electrical blueprint
17. Perform load calculations and determine overcurrent protection and conductor size
18. Compute lighting loads
19. Determine maximum numbers of conductors in conduit
20. Determine wire sizes to prevent excessive voltage drop

Unit 2: Tools and Equipment

1. Terms and definitions
2. Types of conduit benders
3. Wire termination tools
4. Wire and cable pulling equipment
5. Conduit cutting and threading tools
6. Knockout cutters
7. Power actuated tools
8. Types of excavation equipment
9. Describe a tool, and suggest changes to increase its efficiency
10. Bend, cut, ream, and thread 1/2-inch rigid metal conduit
11. Bend EMT stub-ups
12. Make back-to-back bends on 1/2-inch EMT
13. Make offset bends on 1/2-inch EMT
14. Bend and install 1/2-inch EMT
15. Bend a three-point saddle on 1/2-inch EMT
16. Bend a four-point saddle on 1/2-inch EMT
17. Cut, ream, offset, and install connectors on 1/2-inch PVC

Instructional/Task Analysis

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 3: Service

1. Terms and definitions
2. *NEC* requirements for drop clearance and laterals
3. Switch boards and disconnects
4. *NEC* exceptions for overcurrent protection devices
5. Grounding electrodes and ground fault
6. Service entrance devices
7. Emergency and standby systems
8. Procedure for balancing loads
9. Install an overhead raceway with service entrance conductors to a meter base
10. Connect meter base assembly to load center or panel

Unit 4: Transformers

1. Terms and definitions
2. Basic types of transformers
3. Diagrams of the two most commonly used voltage systems
4. *NEC* requirements for dry type transformers
5. *NEC* requirements for oil-filled transformers
6. *NEC* requirements for askarel-filled transformers
7. Function of a buck and boost transformer
8. Transformer locations
9. Installation and termination of transformers
10. Analyze utility company methods for delivering electrical power
11. Draw a three-phase wye-delta transformer
12. Locate and list two exceptions on transformer room construction for dry type transformers
13. Locate and list two exceptions concerning oil-insulated transformers
14. Given amperes, calculate KVA on a three-phase system
15. Test transformer turn ratios
16. Test transformer insulation resistance
17. Connect transformer primary and secondary windings in a delta-wye configuration
18. Test and compare primary apparent power of a transformer to secondary apparent power

Unit 5: Rough-In

1. Terms and definitions
2. Branch circuit and feeder installation
3. Devices used in special circuit installations
4. Requirements for cable tray systems
5. Steps for determining the number of conductors allowed in a conduit, based on cross-sectional area

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 5: Rough-In (continued)

6. Acceptable wiring methods for commercial and industrial projects
7. Optional calculations for additional loads to existing installations
8. Determine the number of conductors allowed to be added to an existing conduit
9. Rough-in a wood framed wall
10. Install outlet boxes on steel rods
11. Install outlet boxes on steel studs using caddy metal stud clips for switch boxes
12. Install masonry boxes in a block wall

Unit 6: Lighting

1. Terms and definitions
2. Basic types of lighting
3. Characteristics of incandescent lighting
4. Characteristics of fluorescent lighting
5. Characteristics of high intensity discharge lamps
6. Characteristics of ballast
7. Methods of calculating light
8. Calculating branch circuits and voltage
9. Switching systems
10. Locate articles in the *NEC* concerning lighting requirements
11. Change a two lamp ballast in a fluorescent fixture
12. Change sockets in a fluorescent fixture
13. Change an HID ballast
14. Change a quartz lamp

Unit 7: Motors and Controllers

1. Terms and definitions
2. Required motor nameplate information
3. Direct current motor theory of operation
4. Types of DC motors
5. Single-phase motor theory of operation
6. Types of single-phase motors
7. Three-phase motor theory of operation
8. Types of three-phase motors
9. Procedure for reversing a three-phase motor
10. Typical supply voltage for three-phase motors
11. Schematics and terminal connections for delta- and wye-wound three-phase motors
12. Motor problems and their typical symptoms

Instructional/Task Analysis

Unit 7: Motors and Controllers (continued)

Related Information: What the Student Should Know

13. Remedies for motor problems
14. Safety rules to observe when working around motors
15. Parts of a magnetic contactor
16. Electrical devices or circuits controlled by contactors
17. Parts of a manual motor starter
18. Types of motor starters
19. Parts of magnetic motor starters
20. Uses of magnetic motor starters
21. Comparison of parts in magnetic contactors with parts in magnetic motor starters
22. Reasons a contactor cannot be used to control a motor
23. Purposes of a coil assembly
24. Parts of a coil assembly

Application: What the Student Should Be Able to Do

25. Interpret nameplate information
26. Describe remedies for common motor problems
27. Use the *NEC* to answer questions about motor control circuits
28. Distinguish between motor starters and contactors
29. Answer questions about uses of contactors and motor starters
30. Disassemble, inspect, and clean a motor
31. Identify run, common, and start terminals on hermetically sealed motors
32. Test capacitors with an ohmmeter
33. Wire a three-phase motor for dual voltages
34. Perform maintenance on a magnetic contactor

Unit 8: Electrical Diagrams and Symbols

1. Terms and definitions
2. Characteristics of wiring diagrams
3. Characteristics of ladder diagrams
4. Characteristics of one-line diagrams
5. Wiring and ladder diagram symbols
6. Major steps in constructing a ladder diagram

7. Construct a basic ladder diagram
8. Identify electrical symbols in a wiring diagram

Unit 9: Two and Three Wire Controls

1. Terms and definitions
2. Typical two-wire pilot devices
3. Advantages of two-wire controls
4. Basic rule for three-wire controls
5. Advantages of three-wire controls
6. Operation of a two-wire control system
7. Operation of a three-wire control system

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 9: Two and Three Wire Controls (continued)

8. Complete a ladder and a wiring diagram of a two-wire control using a thermal switch
9. Draw a ladder diagram of a three wire control with an "on" indicating pilot light
10. Draw a ladder and a wiring diagram of a three-wire control with an "off" indicating pilot light
11. Determine the number and size of conductors needed to operate a two-wire control system
12. Determine the number and size of conductors needed to operate a three-wire control system
13. Wire a two-wire control
14. Wire two float switches to operate a starter (series connection)
15. Wire two float switches to operate a starter (parallel series)
16. Wire a pressure switch to operate a starter with "on" and "off" pilot lights
17. Wire a three-wire control system
18. Wire a multiple station three-wire control
19. Wire a multiple station three-wire control with "on" and "off" pilot lights

Unit 10: Separate Control Circuits

1. Terms and definitions
2. Reasons for separate control circuits
3. Applications for separate control circuits
4. Sources of separate control circuits
5. Typical control transformer schematics and their voltage ratings
6. Necessary changes that must be made to a starter when using a separate control circuit

7. Read and interpret ladder diagrams using separate control circuits
8. Answer questions about control circuits
9. Determine the size and number of conductors needed to operate a separate control circuit
10. Wire a relay and a load with a separate control circuit
11. Wire a three-phase starter to operate by a separate control circuit

Instructional/Task Analysis

Related Information: What the Student Should Know	Application: What the Student Should Be Able to Do
Unit 11: Sequence Control	
1. Terms and definitions 2. Purpose of sequence control 3. Advantages of sequence control 4. Uses of sequence control 5. Purpose of auxiliary contact interlocking 6. Advantages of auxiliary contact interlocking 7. Uses of auxiliary contact interlocking	8. Answer questions related to a sequence control diagram 9. Answer questions related to an auxiliary contact interlocking diagram 10. Wire two starters in sequence 11. Wire two starters with auxiliary contact interlocking
Unit 12: Jogging Controls	
1. Definition of jogging 2. Methods of jogging control 3. Advantages of jogging control 4. Sequence of operation of ladder diagrams	5. Convert ladder diagrams to wiring diagrams 6. Determine the number of conductors needed to operate jogging controls 7. Wire a jog through a lock-stop push button 8. Wire a jog through a two-position selector switch 9. Wire a jog through a two-circuit push button 10. Wire a jog through a control relay
Unit 13: Reversing Starters	
1. Terms and definitions 2. Types of reversing starter construction 3. Types of interlocking methods for reversing starters 4. Types of drum controls 5. Drum switch diagram	6. Describe the sequence of operation of ladder diagrams 7. Determine the number of conductors needed to operate a reversing control 8. Wire a reversing starter with a three-position selector switch 9. Wire a reversing starter with one control station using auxiliary contact and mechanical interlock 10. Wire a reversing starter with one control station using push button interlock and auxiliary contact interlock 11. Wire a reversing starter with two control stations 12. Wire drum switches 13. Wire a reversing starter with jog in both directions

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 14: Special Control Circuits

1. Terms and definitions
2. Parts of a control relay
3. Uses for control relays
4. Parts of a latching relay
5. Reason for using latching relays or contactors
6. Types of timing relays
7. Applications for timing relays
8. How a ground fault indicator works
9. Use of an alarm silencing circuit
10. Build a relay control circuit
11. Wire a latching relay or contactor
12. Wire a timed "on" circuit
13. Wire a timed "off" circuit
14. Energize three starters in a timed sequential order
15. De-energize three starters in a timed sequential order
16. Build a ground fault indicator circuit

Unit 15: Programmable Logic Controllers

1. Terms and definitions
2. Programmable logic controller functions
3. Parts of a programmable logic controller
4. Input devices
5. Output devices
6. Components of a programmable logic controller
7. States of contacts
8. Types of I/O modules
9. Parts of an optical coupler
10. Basic PLC ladder logic symbols
11. Why a stop button is wired normally closed
12. Basic numbering systems used in programmable logic controllers
13. Match I/O devices with their functions
14. Convert between numbering systems

Basic Skills Icons and Classifications

To assist teachers and students in identifying and documenting where academic and workplace skills are being taught, MAVCC has adopted a system that uses icons and a list of specific tasks to identify the skill or skills that are used in each focus assignment, assignment sheet, and job sheet.

A matrix for each of the ten broad skill areas has been included in this eddition and reflects key elements from *What Work Requires of Schools: A SCANS Report for America 2000*, a 1991 study by the U.S. Department of Labor; *Workplace Basics: The Skills Employers Want*, a three-year study conducted jointly by the American Society for Training and Development (ASTD) and the United States Department of Labor (DOL); and other national and state sources.

Each of the ten broad skill areas—reading, writing, mathematics, science, oral communication, interpersonal or relating, critical thinking, employability, social studies, and technology—is represented by the icon presented below.

Reading Skills

- Reading Comprehension
- Research/Reference
- Functional Reading

Writing Skills

- Language
- Composition
- Research
- Functional Writing

Math Skills

- Operation and Calculation
- Math Application
- Data Analysis and Display
- Functional Math

Basic Skills Icons and Classifications

Science Skills

- General Science
- Life Science
- Physical Science
- Earth Science

Oral Communication Skills

- Oral Presentation
- Listening
- Interactive Communication

Interpersonal or Relating Skills

- General Relating
- Teamwork/Cooperation
- Leadership/Influence

Critical Thinking Skills

- Cognitive Activities

Employability Skills

- Job Search/Selections
- Job Acquisition/Development

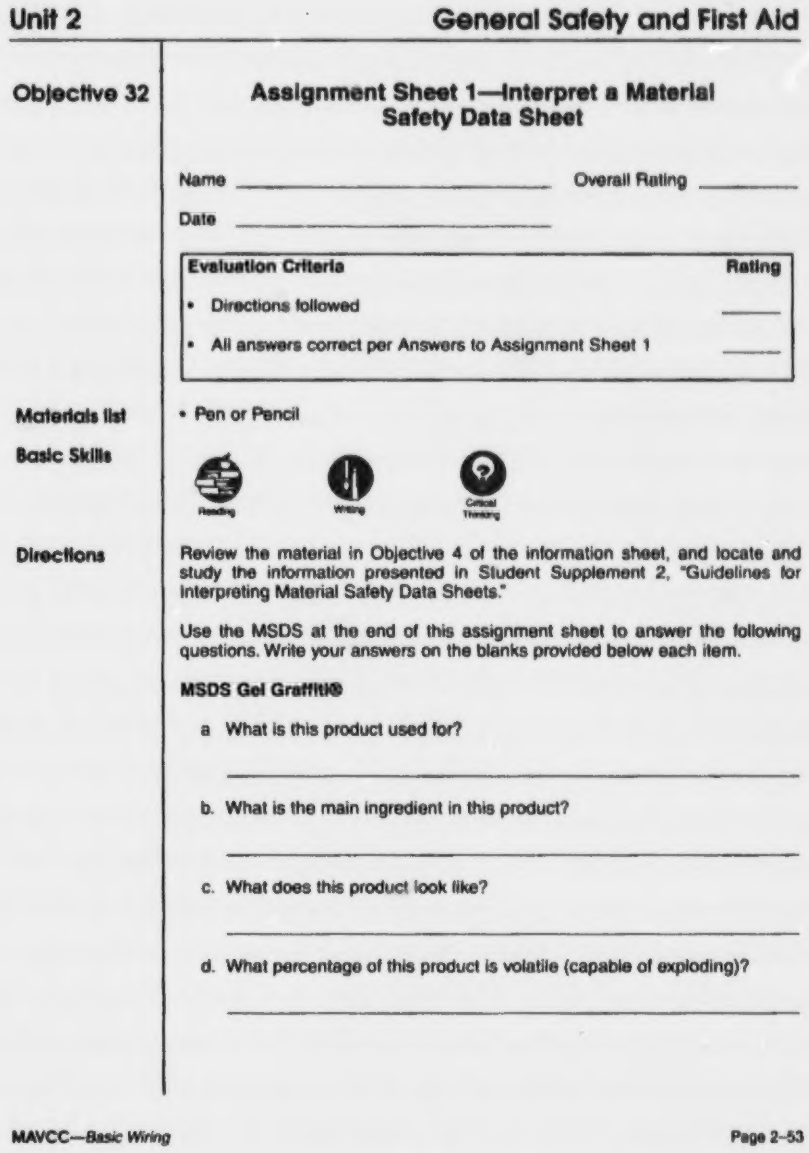
Social Studies Skills

- Information Analysis
- Social Studies Application
- Functional Social Studies

Basic Skills Icons and Classifications

When an activity involving one of these basic skills is identified, the corresponding icon is placed in the left-hand margin of the focus assignment, assignment sheet, and job sheet. Skills training is further defined by classifying specific skills that are required. (See skills list that may be found on each basic skills matrix.)

Example:



Unit 2 **General Safety and First Aid**

Objective 32

Assignment Sheet 1—Interpret a Material Safety Data Sheet

Name ______________________ Overall Rating ________

Date ______________________

Evaluation Criteria	**Rating**
• Directions followed	_____
• All answers correct per Answers to Assignment Sheet 1	_____

Materials list • Pen or Pencil

Basic Skills

Reading Writing Critical Thinking

Directions Review the material in Objective 4 of the information sheet, and locate and study the information presented in Student Supplement 2, "Guidelines for Interpreting Material Safety Data Sheets."

Use the MSDS at the end of this assignment sheet to answer the following questions. Write your answers on the blanks provided below each item.

MSDS Gel Graffiti®

a What is this product used for?

____

b. What is the main ingredient in this product?

____

c. What does this product look like?

____

d. What percentage of this product is volatile (capable of exploding)?

____

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BASIC SKILLS MATRIX

Reading Skills

	Reading Comprehension									Research/Reference								Functional Reading					
UNITS OF INSTRUCTION	Gain factual information	Distinguish fact, opinion and inference	Recognize stereotyping and bias	Recognize propaganda	Analyze cause and effect	Draw conclusions	Make generalizations	React to written material	Apply word analysis techniques	Select useful resources	Locate resources	Find materials in library	Use standard references	Use in-book reference tools	Use audiovisual media	Use computer data base	Use magazines and newspapers	Interpret forms and records	Follow written instructions	Interpret graphics and symbols	Use content area vocabulary	Interpret abbreviations/acronyms	Read aloud
Unit 1.										X									X	X			
Unit 2.																			X				
Unit 3.																			X				
Unit 4.	X																		X	X			
Unit 5.																			X				
Unit 6.													X						X				
Unit 7.	X										X								X			X	
Unit 8.																			X	X			
Unit 9.																			X	X			
Unit 10.					X						X		X						X	X	X		
Unit 11.																			X	X	X		
Unit 12.																			X	X			
Unit 13.																			X	X			
Unit 14.																			X				
Unit 15.																			X				
Unit 16.	X					X													X	X	X		

Commercial and Industrial Wiring

BASIC SKILLS MATRIX

Writing Skills

UNITS OF INSTRUCTION	Language		Composition								Research					Functional Writing						
	Use standard grammar, spelling, and capitalization	State ideas clearly	Use complete sentences	Develop preliminary outline	Use topic sentences	Use introductory/closing paragraphs	Compose reports	Compose essays	Proofread and edit	Construct graphics and symbols	Take notes	Use note cards	Create bibliography	Use footnotes	Outline material	Complete forms and records	Write instructions	Write letters	Write job applications	Write resumes	Use word processing	Use computer graphics
Unit 1.										X												
Unit 2.																						
Unit 3.																						
Unit 4.										X												
Unit 5.																						
Unit 6.																						
Unit 7.	X	X																				
Unit 8.										X												
Unit 9.										X												
Unit 10.		X								X												
Unit 11.		X								X												
Unit 12.										X												
Unit 13.		X	X							X												
Unit 14.			X							X												
Unit 15.																						
Unit 16.		X					X			X						X						

BASIC SKILLS MATRIX

Math Skills

	Operation and Calculation														Math Application										
UNITS OF INSTRUCTION	Round off numbers	Estimate answers	Use scientific notations	Use exponential notations	Calculate with whole numbers	Calculate with fractions	Calculate with decimals	Convert whole numbers to fractions	Convert whole numbers to decimals	Solve numerical expressions	Solve formulae and equations	Obtain squares and square roots	Converts units of measure	Perform metric calculations	Solve word problems	Select/apply mathematical formula	Select/apply mathematical procedure	Use English and metric measures	Solve time/rate/distance problems	Solve ratio/proportion problems	Solve percent problems	Apply techniques of scaling	Apply algebra principles	Apply geometry principles	Apply trigonometry principles
Unit 1.					X		X								X		X								
Unit 2.																									
Unit 3.																									
Unit 4.					X		X																		
Unit 5.							X								X										
Unit 6.																									
Unit 7.																									
Unit 8.																									
Unit 9.							X																		
Unit 10.							X										X								
Unit 11.																									
Unit 12.							X										X								
Unit 13.							X										X								
Unit 14.																									
Unit 15.																									
Unit 16.		X			X																				

Commercial and Industrial Wiring

BASIC SKILLS MATRIX

Math Skills (continued)

	Data Analysis and Display										Functional Math													
UNITS OF INSTRUCTION	Interpret charts and tables	Interpret graphs	Collect/record data	Apply sampling techniques	Apply principles of probability	Construct charts and tables	Construct graphs	Calculate statistics	Interpret statistics	Interpret plans/blueprints	Make measurements	Perform banking transactions	Make change	Solve practical problems	Calculate gross earnings	Solve income/expense problems	Prepare a budget	Calculate interest	Solve interest problems	Calculate sales tax	Determine income tax	Use calculator for computation	Use computer for computation	Use computer spreadsheets
Unit 1.																								
Unit 2.																								
Unit 3.																								
Unit 4.			X																					
Unit 5.																								
Unit 6.																								
Unit 7.																								
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Unit 9.																								
Unit 10.																								
Unit 11.																								
Unit 12.																								
Unit 13.																								
Unit 14.																								
Unit 15.																								
Unit 16.																								

BASIC SKILLS MATRIX

Science Skills

UNITS OF INSTRUCTION	General Science									Life Science						
	Apply computing skills	Apply scientific method of inquiry	Conduct experiments/Practicals	Investigate science ethics	Investigate science history	Investigate/apply economics in technology	Use scientific instruments	Investigate/apply technology	Collect specimens	Identify/classify living organisms	Investigate biological history of the earth	Investigate food chains, webs, pyramids	Investigate/apply principles of human development	Investigate/apply principles of genetics/heredity	Investigate/apply principles of anatomy/physiology	Investigate health issues
Unit 1.	X	X		X		X	X	X								
Unit 2.				X	X	X	X	X								
Unit 3.	X		X	X		X	X	X								
Unit 4.	X	X	X	X		X	X	X								
Unit 5.	X	X	X	X		X	X	X								
Unit 6.	X	X	X	X		X	X	X								
Unit 7.	X	X	X	X		X	X	X								
Unit 8.			X	X		X	X	X								
Unit 9.	X	X	X	X		X	X	X								
Unit 10.	X		X	X		X	X	X								
Unit 11.	X		X	X		X	X	X								
Unit 12.			X	X		X	X	X								
Unit 13.			X	X		X	X	X								
Unit 14.			X	X		X	X	X								
Unit 15.	X	X	X	X		X	X	X								
Unit 16.	X	X	X	X		X	X	X								

BASIC SKILLS MATRIX

Science Skills (continued)

	Physical Science					Earth Science										
UNITS OF INSTRUCTION	Analyze/classify matter	Investigate forms/changes of matter	Investigate forms/changes of energy	Investigate/apply chemical properties	Investigate/apply physical laws	Investigate physical characteristics of the earth	Investigate geological history of the earth	Investigate physical forces acting on the earth	Solve problems of longitude, latitude, and time zones	Investigate conservation of physical resources	Investigate conservation of living resources	Investigate issues of environmental impact	Apply science principles to environmental issues			
Unit 1.																
Unit 2.																
Unit 3.																
Unit 4.																
Unit 5.																
Unit 6.																
Unit 7.																
Unit 8.																
Unit 9.																
Unit 10.																
Unit 11.																
Unit 12.																
Unit 13.																
Unit 14.																
Unit 15.																
Unit 16.																

BASIC SKILLS MATRIX

Oral Communication Skills

UNITS OF INSTRUCTION	Oral Presentation									Listening				Interactive Communication									
	Make informative presentations	Make persuasive presentations	Present personal opinion/viewpoint	Use good speaking techniques	Select/use words effectively	Use effective body language	Present appropriate appearance	Integrate audio and/or visual materials into oral presentations	Adapt presentation to specific audience	Apply active listening skills	Distinguish fact, opinion, and inference	Draw conclusions/make generalizations	Analyze/identify point of view	Give/follow oral directions	Apply questioning techniques	Conduct/receive interviews	Analyze/apply nonverbal communication	Work effectively in a group	Communicate with clients/customers/patients	Communicate with co-workers	Communicate with supervisors	Communicate with professional colleagues/associates	Apply telephone etiquette
Unit 1.																							
Unit 2.																							
Unit 3.																							
Unit 4.																							
Unit 5.																							
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Unit 12.																							
Unit 13.																							
Unit 14.																							
Unit 15.																							
Unit 16.																							

BASIC SKILLS MATRIX

Interpersonal or Relating Skills

	General Relating												Teamwork/Cooperation														
UNITS OF INSTRUCTION	Investigate/apply communication process models	Analyze/apply nonverbal communication	Investigate/apply cross-cultural communication	Interact with co-workers	Interact with supervisors	Interact with clients/customers/patients	Interact with professional colleagues/associates	Interact with family/friends	Participate in group activities	Participate in industrial relations/functions	Identify personal values/attitudes	Apply information to life experiences	Identify values/attitudes	Identify needs/drives	Select/apply appropriate behavior	Investigate/identify personal styles	Investigate/identify group/corporate climate	Give/receive feedback	Identify hidden purposes	Investigate/apply group dynamics	Control undesirable/inappropriate behavior	Resolve conflicts	Clarify goals/objectives	Devise "win/win" situations	Build consensus	Generate ideas	Present point of view
Unit 1.																											
Unit 2.																											
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Unit 7.																											
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Unit 9.																											
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Unit 11.																											
Unit 12.																											
Unit 13.																											
Unit 14.																											
Unit 15.																											
Unit 16.																											

BASIC SKILLS MATRIX

Interpersonal or Relating Skills (continued)

Leadership/Influence

UNITS OF INSTRUCTION	Analyze/apply leadership styles	Analyze/apply management styles	Obtain confidence of others	Develop esteem in self/others	Persuade others	Analyze/apply motivation techniques	Provide positive coaching																		
Unit 1.																									
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Unit 12.																									
Unit 13.																									
Unit 14.																									
Unit 15.																									
Unit 16.																									

Commercial and Industrial Wiring

BASIC SKILLS MATRIX

Critical Thinking

UNITS OF INSTRUCTION	Cognitive Activities Collect/record information	Identify critical elements/issues	Define a problem	Identify underlying causes	Apply a problem-solving model	Analyze/synthesize information	Identify/analyze underlying assumptions	Draw conclusions	Predict results/outcomes	Identify/evaluate consequences	Identify/develop alternatives	Evaluate alternatives	Select an alternative	Devise a solution	Create a finished product	Apply intuitive thinking techniques	Transfer knowledge/training to new situations	Apply new technology	Develop an action plan	Evaluate results/outcomes
Unit 1.																				
Unit 2.																				
Unit 3.																				
Unit 4.	X																			
Unit 5.																				
Unit 6.																				
Unit 7.	X	X	X	X	X	X	X	X			X	X	X	X			X			
Unit 8.																				
Unit 9.																				
Unit 10.		X				X									X					X
Unit 11.																				
Unit 12.																				
Unit 13.																				
Unit 14.						X		X	X											
Unit 15.																				
Unit 16.	X	X	X	X	X	X	X	X	X	X				X	X		X			X

BASIC SKILLS MATRIX

Employability Skills

UNITS OF INSTRUCTION	Job Search/Selections								Job Acquisition/Development													
	Analyze personal occupational aptitudes/ preferences	Investigate employment prospects of a career field/occupation	Investigate training requirements for a career field/occupation	Investigate benefits of a career field/ occupation	Compare/evaluate career options	Develop personal career path	Locate appropriate jobs	Analyze duties/requirements/benefits of specific job	Master specific job task/procedure	Complete job-related applications	Write a letter of application	Write personal resume	Interview for a job	Apply business etiquette	Practice good work habits/attitudes	Practice good personal presentation	Develop self confidence/esteem	Develop effective leadership	Deal effectively with supervisors	Deal effectively with co-workers	Deal effectively with professional colleagues/associates	Deal effectively with customers/ clients/patients
Unit 1.																						
Unit 2.																						
Unit 3.																						
Unit 4.									X	X					X		X					
Unit 5.									X	X					X		X					
Unit 6.									X	X					X		X					
Unit 7.									X	X					X		X					
Unit 8.																						
Unit 9.									X	X					X		X					
Unit 10.									X	X					X		X					
Unit 11.									X	X					X		X					
Unit 12.									X	X					X		X					
Unit 13.																						
Unit 14.									X	X					X		X					
Unit 15.																						
Unit 16.									X	X					X		X					

BASIC SKILLS MATRIX

Social Studies Skills

	Information Analysis						Social Studies Application														
UNITS OF INSTRUCTION	Collect/record data	Interpret graphical information	Construct graphical information	Interpret maps/globes	Interpret statistical information	Analyze/Interpret demographic information	Investigate/apply U.S. history	Investigate/apply world history	Investigate/apply U.S. geography	Investigate/apply world geography	Investigate/apply principles of government/politics	Investigate/apply principles of economics	Investigate/apply principles of ethics	Investigate/apply principles of psychology	Investigate/apply principles of sociology	Investigate/apply cross-cultural studies					
Unit 1.																					
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Unit 12.																					
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Unit 14.																					
Unit 15.																					
Unit 16.																					

BASIC SKILLS MATRIX

Social Studies Skills
(continued)

	Functional Social Studies																					
UNITS OF INSTRUCTION	Practice responsible personal economics	Prepare a personal budget	Use credit responsibly	Practice good work ethics	Participate in industrial relations	Interact with people of different races/cultures	Investigate/participate in government	Investigate/apply American legal practices	Select/use sources of information on current events	Analyze current events	Analyze consumer issues	Analyze social issues	Analyze conservation/ecology issues	Analyze social impact of science/technology	Analyze economic impact of science/technology							
Unit 1.																						
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Unit 11.																						
Unit 12.																						
Unit 13.																						
Unit 14.																						
Unit 15.																						
Unit 16.																						

Tools, Equipment, and Materials List

- Awl
- Ballast
  - Two-lamp
  - HID
- Bar hanger, expandable
- Beam, 2" x 4"
- Benders
  - Republic
  - EMT
  - PVC
- Blueprint, construction
- Bolt, stove
- Box clips
- Boxes - various sizes
  - Fan
  - Handy
  - 1900
  - Masonry
  - Octagon
  - One-gang
  - Outlet
  - Switch
  - Two-gang
- Bushings, insulating
- Cable - various lengths
  - Copper, #2 and #4
  - EMT
  - TFF, #16
  - TFFN, #16
  - THHN - white, black, blue, and red
  - THWN, #16
- Capacitors–start or run, 300V nonelectrolytic
- Center punch
- Clamps, rod hanger
- Clips
  - Metal stud
  - MF
- Coils, magnetic
- Compressed air
- Compressor units, hermetically sealed
- Conduit, rigid metal
- Connectors
  - Compression
  - EMT
  - PVC
  - Setscrew

Tools, Equipment, and Materials List

- Contactor
- Couplings
  - EMT
  - Setscrew
- Cutting oil
- Dual voltage motor
- Fixture sockets, two-pin
- Folding rule with sliding scale
- Fuses
- Fuse block
- Fuse holder
- Gear puller
- Generator, function
- Hacksaw
- Hacksaw blade
- Hammer
  - Ball peen
  - Soft faced
- Jumper, wire or test
- Knife
  - Electricians
  - Skinning
- Lamp
- Level
- Load center, SN -100 amp, 3-phase, 3-wire
- Locknuts, 1 1/4"
- Lock stop device
- Machine oil
- Measuring tape
- Megger tester, with leads
- Meter base, 3ϕ
- Motor cleaning fluid
- Motors
  - Dual voltage
  - Split phase
    - 3ϕ, 3/4 HP
- Mounting Board
- Nails, mounting
- Nipple, reamed
- Nuts, wire
- Nut driver set
- Ohmmeter
- Paper
- Pencil, marking
- Pilot lights, 120V with and without enclosures
- Pipe
  - Die
  - Vise

- Pliers
  - Lineworkers
  - Needle nose
- Pouch tools
- Power supply
- Push buttons
  - Normally open
  - Normally closed
  - Two-circuit, N/O, N/C
- PVC cement
- Quartz lamp
- Rags
  - Polishing
  - Shop
- Reaming tool
- Relays
  - 2-pole, control
  - 4-pole w/24V coil
  - 4-pole w/120V coil
  - 4-pole latching
  - General purpose
  - Time delay w/timed closed contacts
  - Time delay w/timed open contacts
- Resistors, various
- Rod, 1/4″
- Rule
- Safety glasses
- Screwdriver set
- Screws
  - Metal tapping #12
  - Sheet metal
- Service entrance cap
- Straps
  - One hole
  - Pipe
  - Rigid conduit
- Starter
  - 3-phase open
  - 3-phase w/120V coil
  - 3-phase w/normally closed auxiliary contacts
  - Motor
  - Reversing w/mechanical interlock
- Stations, control
  - Forward/reverse/stop
  - Start/stop
  - Three element
  - Two element

Tools, Equipment, and Materials List

- Switches
  - Drum, for polyphase motors
  - Float
  - Pressure
  - Three position with enclosure
  - Two position selectors, N/O
- Tape measure
- Thermometer, centigrade scale
- Time clock, 24 hour
- Transformers
  - Control
  - Various voltages
- Voltmeters (2), one with 600V scale
- Wall
  - Framed w/2″ x 4″ studs
  - Mock-up
  - Steel stud
- Wire
  - Brush
  - Markers
- Wrench sets
  - Combination
  - Small

Unit 1

Blueprint Reading and Load Calculations

Unit Contents

Teacher Page

Teacher Components

Suggested Activities 1–3

Answers to Assignment Sheets 1–7

Written Test 1–9

Answers to Written Test 1–21

Teacher Supplement

Participants at a Construction Site 1–25

Transparency Masters

1—Alphabet of Lines 1–27
2—Electrical Floor Plan 1–29
3—Floor Plan 1–31
4—Foundation Plan 1–33
5—Elevations 1–35
6—Plot Plan 1–37
7—Details 1–39

Student Page

Student Components

Objective Sheet 1–3

Information Sheet 1–5

* Focus Assignment

Select Participants and Describe Their Functions at a Construction Site 1

* Assignment Sheets

1—Construct an Electrical Blueprint 3
2—Perform Load Calculations and Determine Overcurrent Protection and Conductor Size 5
3—Compute Lighting Loads 17
4—Determine Maximum Numbers of Conductors in Conduit 19
5—Determine Wire Sizes to Prevent Excessive Voltage Drop 21

* Focus Assignment and Assignment Sheets are located in Student Workbook 1.

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make copies of any teacher supplements that will be provided for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

  TM1—Alphabet of Lines (Objective 8)
  TM2—Electrical Floor Plan (Objective 14)
  TM3—Floor Plan (Objective 14)
  TM4—Foundation Plan (Objective 14)
  TM5—Elevations (Objective 14)
  TM6—Plot Plan (Objective 14)
  TM7—Details (Objective 14)

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Suggested Activities

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Have students complete the focus assignment to introduce topics presented in unit of instruction.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheets. Review with students the criteria for evaluation of these activities.

Teaching Suggestions

- Take students on a field trip to a construction site. Arrange for students to observe both the blueprints and the actual work on site.
- Have a representative from a local engineering firm talk to the class about the importance of knowing how to read various types of blueprints.
- Invite a local inspector to class to discuss pertinent codes and requirements. Conduct a question and answer period to enhance the discussion.
- Show students examples of various types of blueprints. Have the class identify the symbols used.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the assignment sheets. Rate the student using the criteria listed on each assignment sheet. See Answers to Assignment Sheets for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.
- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Suggested Activities

Resources Used in Developing This Unit

Print Media

- Kaltwasser, Stan and Gary Flowers. *Commercial and Industrial Wiring.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.
- Mullin, Ray C. and Robert L. Smith. *Electrical Wiring—Commercial.* Albany, NY: Delmar Publishers, Inc., 1990.
- *National Electrical Code, 2002.* Quincy, MA: National Fire Protection Association, 2001.
- *National Electrical Code 1999.* Quincy, MA: National Fire Protection Association, 1998.
- *National Electrical Code 1993.* Quincy, MA: National Fire Protection Association, 1992.
- Teague, Cash and Garner Pewewardy. *Industrial Electricity: In-Plant Distribution.* Stillwater, OK: Oklahoma Curriculum and Instructional Materials Center, 1984.

Suggested Supplemental Resources

Print Media

- *2002 NEC Analysis of Changes.* Quincy, MA: National Fire Protection Association, 2001.

  Provides a detailed view of the most important changes in the 2002 NEC

- *NEC 2002 Handbook.* Quincy, MA: National Fire Protection Association, 2001.

  Contains complete Code text plus commentary, photos, and full-color graphics

  The publication(s) listed above can be ordered from:

  National Fire Protection Association
  1 Batterymarch Park
  Quincy, MA 02269-9101
  1-800-344-3555
  www.nfpa.org

- Early, Mark W., et al. *Illustrated Changes in the National Electrical Code.* Delmar Publishers, Inc. 2002.

  Provides a detailed view of the most important changes in the 2002 NEC

Suggested Activities

- Herman, Stephen L. *Electrician's Technical Reference: Electrical Theory and Calculations.* Delmar Publishers, Inc. 2002.
- Herman, Stephen L. *Electrician's Technical Reference: Industrial Electronics.* Delmar Publishers, Inc. 1999.
- Loyd, Richard. *Electrician's Technical Reference: Wiring Methods.* Delmar Publishers, Inc. 1999.
- Miller, Chris. *Illustrated Guide to the National Electrical Code,* 2nd ed. Delmar Publishers, Inc. 2002.

  Conveniently groups Code requirements according to type of occupancy, and contains 600 illustrations
- Mullin, Ray and Robert Smith. *Electrical Wiring Commercial,* 11th ed. Delmar Publishers, Inc. 2002.
- O'Riley, Ronald. *Electrical Grounding,* 6th ed. Delmar Publishers, Inc. 2002.
- Smith, Robert and Stephen Herman. *Electrical Wiring Industrial,* 11th ed. Delmar Publishers, Inc. 2002.
- Surbrook, Truman and Jonathan Althouse. *Interpreting the National Electrical Code,* 6th ed. Delmar Publishers, Inc. 2002.

  Offer practical examples to illustrate how articles in the Code are applied
- Titus, Patricia A., et al. *Illustrated Dictionary for Electrical Workers,* 2nd ed. Delmar Publishers, Inc. 2002.

Answers to Assignment Sheets

Assignment Sheet 1

Construct an Electrical Blueprint—Answers may vary according to individual students. Look for basic understanding of concepts and correct use of symbols.

Assignment Sheet 2

Perform Load Calculations and Determine Overcurrent Protection and Conductor Size

a. 125 Amp Fuse, #12 AWG THHN
b. 150 Amp Fuse, #1 AWG THHN
c. 70 Amp Fuse, #6 AWG THWN
d. 350 Amp Fuse, 500 kcmil THW
e. 30 Amp Fuse, #10 AWG TW
f. 30 Amp Fuse, #10 AWG TW
g. 45 Amp Fuse, #8 AWG THHN
h. 40 Amp Fuse, #8 AWG THHN
i. 50 Amp Fuse, #8 AWG THHN
j. 200 Amp Fuse, 3/0 THHN
k. 80 Amp Fuse, #4 AWG THW
l. 80 Amp Fuse, #4 AWG THW (Maximum)
40 Amp Fuse, #10 AWG THW
m. 30 Amp Fuse, #10 AWG THHN
n. 10 Amp Fuse, #14 AWG THWN
o. 10 Amp Fuse, #14 AWG THWN
p. 50 Amp Fuse, #8 AWG THHN
q. 1600 Amp Fuse, 4-600 KCMIL, Paralled per phase (maximum)
1000 Amp Fuse, 3-35 KCMIL, Paralled per phase
r. 1600 Amp Fuse Ground Fault Protected,
4-600 kcmil, paralleled per phase

Assignment Sheet 3

Compute Lighting Loads

a. 168.75 amps
b. 5.31 amps
c. 21.5 amps
d. 26.82 amps
e. 11.25 amps

Assignment Sheet 4

Determine Maximum Numbers of Conductors in Conduit

a. 4
b. 6
c. 141
d. 10
e. 16
f. 216
g. 265

Answers to Assignment Sheets

Assignment Sheet 5

Determine Wire Sizes to Prevent Excessive Voltage Drop

a. #4 AWG
b. #8 AWG
c. #4 AWG
d. #1/0

Written Test

Name ______________________________

Date ______________________ Score __________

Objective 1

Match the terms related to blueprint reading and load calculations with their definitions. Write the correct numbers in the blanks.

1. Blueprint
2. Blueprint lines
3. Branch circuit
4. Demand factor
5. Feeder circuit
6. Specifications
7. Symbol
8. Voltage drop

_____ a. Set of conventional symbols to depict an object

_____ b. A reduction in available voltage at the end of a circuit

_____ c. The circuit that extends from the last overcurrent protection device to the outlets

_____ d. Copy of the original detailed drawings of a structure

_____ e. All circuit conductors between the service equipment of the source of a separately derived system and final branch circuit overcurrent device

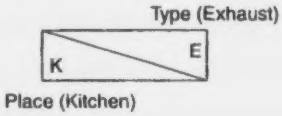
_____ f. A detailed set of written instructions that explains the drawing

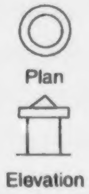
_____ g. An arbitrary sign that has been standardized and is used to represent an object, quantity, or method

_____ h. The ratio of the maximum demand of a system or part of a system, to the total connected load of a system or the part of the system under consideration

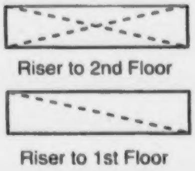
Objective 2

Identify the following mechanical symbols. Write your answers in the blanks provided.

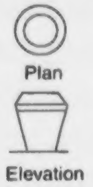




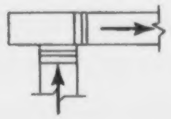
a. ______________________ b. ______________________


Riser to 2nd Floor
Riser to 1st Floor

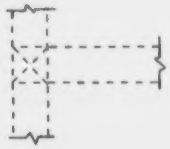
c. ____________________


Plan
Elevation

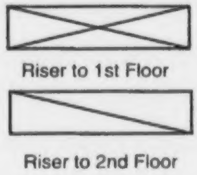
d. ____________________



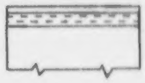
e. ____________________



f. ____________________


Riser to 1st Floor
Riser to 2nd Floor

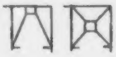
g. ____________________



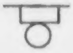
h. ____________________

Objective 3

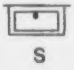
Identify the following plumbing symbols. Write your answers in the blanks provided.



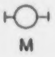
a. ____________________



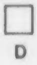
b. ____________________



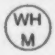
c. ____________________



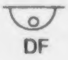
d. ____________________



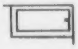
e. ____________________



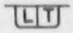
f. ____________________



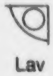
g. ____________________



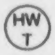
h. ____________________



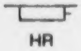
i. ______________________



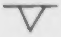
j. ______________________



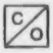
k. ______________________



l. ______________________

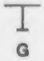


m. ______________________

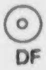


n. ______________________

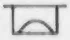
o. ______________________



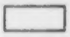
p. ______________________



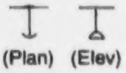
q. ______________________



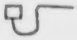
r. ______________________



s. ______________________



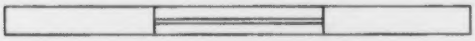
t. ______________________



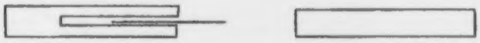
u. ______________________

Objective 4

Identify the following structural symbols. Write your answers in the blanks provided.

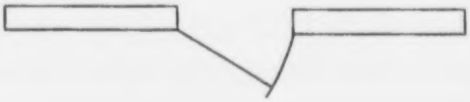


a. ______________________

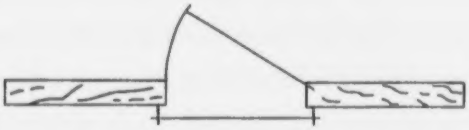


b. ______________________

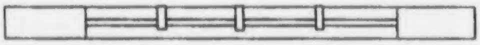
Written Test



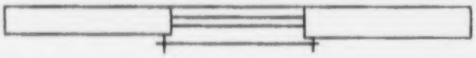
c. ______________________



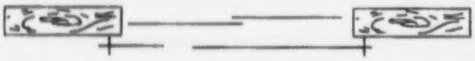
d. ______________________



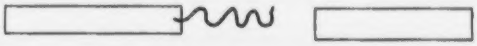
e. ______________________



f. ______________________



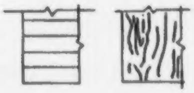
g. ______________________

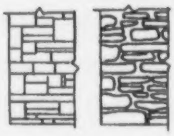


h. ______________________

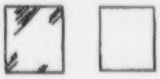
Objective 5

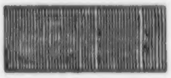
Identify the following architectural symbols. Write your answers in the blanks provided.



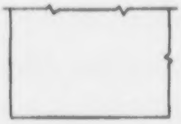


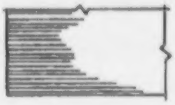
a. ______________________ b. ______________________



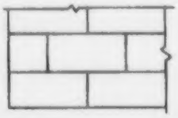


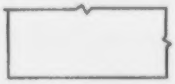
c. ______________________ d. ______________________





e. ______________________ f. ______________________





g. ______________________ h. ______________________

Objective 6

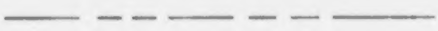
Identify the following electrical symbols. Write your answers in the blanks provided.

S_3

a. ______________________

S_2

b. ______________________



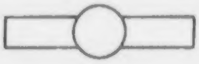
c. ______________________

$\boxed{H}$

d. ______________________

S_f

e. ______________________



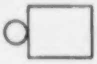
f. ______________________

$\underline{S}$

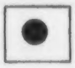
g. ______________________

S_p

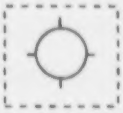
h. ______________________



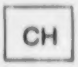
i. ______________________



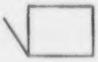
j. ______________________



k. ______________________



l. ______________________



m. ______________________

S

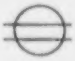
n. ______________________

S_{cb}

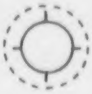
o. ______________________

M_s

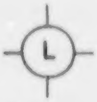
p. ______________________



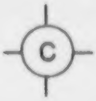
q. ______________________



r. ______________________



s. ______________________



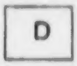
t. ______________________

S_D

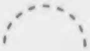
u. ______________________

S_{wp}

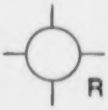
v. ______________________



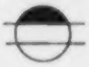
w. ______________________



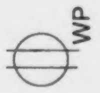
x. ______________________



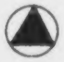
y. ______________________



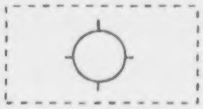
z. ______________________



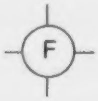
aa. ______________________



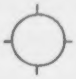
bb. ______________________



cc. ______________________



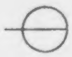
dd. ______________________



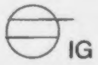
ee. ______________________

S_4

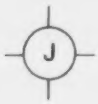
ff. ______________________



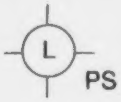
gg. ______________________



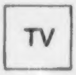
hh. ______________________



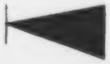
ii. ______________________



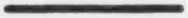
jj. ______________________



kk. ______________________



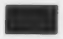
ll. ______________________



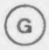
mm. ______________________

Objective 7

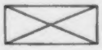
Identify the panel, circuit, and other electrical symbols. Write your answers in the blanks provided.



a. ______________________

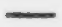


b. ______________________

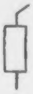


c. ____________________

d. ____________________

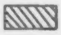


e. ____________________

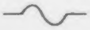


f. ____________________

g. ____________________



h. ____________________



i. ____________________

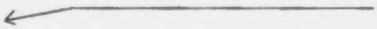
j. ____________________

Objective 8

Match the names of types of blueprint lines with their pictures and descriptions. Write the correct numbers in the blanks. Pictures and descriptions continue on the next page.

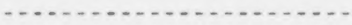
1. Object lines
2. Center lines
3. Leaders
4. Extension lines
5. Section lines
6. Cutting-plane lines
7. Hidden lines
8. Dimension lines
9. Break lines

_____ a.



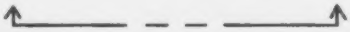
Used to connect a note or dimension to a part of the building

_____ b.



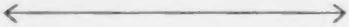
Short dashes used to show lines that are not visible from that view

_____ c.

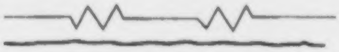


Heavy lines consisting of a series of one long and two short dashes with arrows at each end pointing away from the area that is cut away for the purpose of sectioning

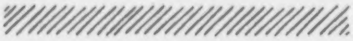
_____ d.



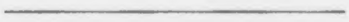
Thin unbroken lines upon which building dimension are placed

____ e. 

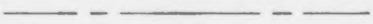
Used when an area cannot or should not be drawn in its entirety

____ f. 

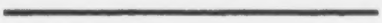
A series of lines of various shapes or symbols used to depict an area that is a cross section of the whole object and also depict the type of material to be used in construction

____ g. 

Extend, but do not touch, the object lines and permit dimension lines to be drawn between them

____ h. 

A series of short and long dashes used to designate the centers of doors, windows, and circles and to provide reference points for dimensioning

____ i. 

Show the main outline of the building including exterior walls, interior partitions, porches, patios, driveways, and interior walls; should be the outstanding lines on a drawing

Objective 9

List four typical electrical specifications.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

Objective 10

Complete the following concerning minimum requirements for electrical devices.

____ a. Rooftop heating, air conditioning, and refrigeration equipment must have a ______________ GFCI volt receptacle within 25 feet of equipment.

____ b. Show windows must have one receptacle for each ________ linear feet.

_____ c. A unit of not less than that specified in *NEC* Table 220.3(A) for occupancies listed therein shall constitute the minimum lighting load for each ________________________ of floor area.

_____ d. Disconnects are required by code for ________________________ and ________________________ and each service, feeder, or branch circuit at the point where it originates and shall be legibly marked.

Objective 11

Determine the following motor-circuit wire sizes by using the *NEC*.

a. 1hp 240 volts 1ϕ ______________________________

b. 2hp 240 volts 3ϕ ______________________________

c. 3hp 240 volts 3ϕ ______________________________

d. 7.5hp 240 volts 3ϕ ______________________________

e. 15hp 240 volts 3ϕ ______________________________

Objective 12

Select true statements concerning load calculations by placing an "X" in the blanks next to the true statements.

_____ a. Feeder size is determined by branch circuit loads to be supplied.

_____ b. For 3-wire DC or single phase AC, 4-wire, 3 phase and 5-wire, 2 phase systems, a further demand factor of 70% shall be permitted for that portion of the unbalanced load in excess of 200 amperes. No reduction is permitted on the neutral conductor concerning electric discharge lighting.

_____ c. Loads for branch circuit calculations are classified in two separate groups: general purpose receptacle loads and motor loads.

_____ d. Concerning temperature calculations, no conductor shall be used in such a manner that is operating temperature will exceed that designated for the type of insulated conductor involved.

Objective 13

Select true statements concerning voltage drop by placing an "X" in the blanks next to the true statements.

_____ a. If voltage drop is too great, electrical equipment can overheat.

_____ b. Voltage drop must be considered when feeder and branch-circuit conductors are selected.

_____ c. The equation for calculating single phase voltage drop is $VD = \frac{2L \times K \times I}{A}$

_____ d. The values that are used when determining voltage drop are:

VD—Voltage drop
L—One-way or total length of circuit conductor
K—A constant for conductor material
I—Current through the conductor
A—Area of conductor in circular mils

_____ e. The equation for calculating three-phase voltage drop is

$$VD = \frac{L \times K \times I \times 1.732}{A}$$

Objective 14

Match types of blueprints with their definitions.

1. Electrical floor plan
2. Floor plan
3. Foundation plan
4. Elevations
5. Plot plan
6. Details

_____ a. Shows location of building in relationship to layout of land and location of utilities and site lighting

_____ b. Clarify placement of exterior lighting and power outlets

_____ c. Similar to electrical but shows equipment, wall, and structural support locations

_____ d. Shows locations of switches, outlets, lighting, and special equipment

_____ e. Clarify specific installation requirements such as j-bolts for site lighting or special equipment mounting devices

_____ f. Shows structural support characteristics of building which are pertinent when planning conduit runs

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a. 2
b. 8
c. 3
d. 1
e. 5
f. 6
g. 7
h. 4

Objective 2

a. Duct section notation
b. Rainproof ventilator
c. Duct section, exhaust return
d. Standard ventilator
e. Fan flexible connection
f. Duct connection below joist
g. Duct section, supply
h. Louver 8 screen air intake

Objective 3

a. Shower stall
b. Water closet (low tank)
c. Plain kitchen sink
d. Meter
e. Drain
f. Water heater
g. Drinking fountain (wall type)
h. Corner bath
i. Laundry tray
j. Corner lavatory
k. Hot water tank
l. Hose rack
m. Vacuum outlet
n. Cleanout
o. Roof sump
p. Gas outlet
q. Drinking fountain (pedestal type)
r. Urinal (stall type)
s. Wash sink
t. Shower head
u. Garage drain

Objective 4

a. Plan view of single window in frame wall
b. Plan view of interior pocket door
c. Plan view of interior hinged door
d. Plan view of exterior door in wood frame wall
e. Plan view of multiple windows in frame wall
f. Plan view of double hung window in frame wall
g. Plan view of exterior sliding door in wood frame wall
h. Plan view of folding door

Answers to Written Test

Objective 5

a. Wood
b. Stone
c. Glass
d. Sheet metal flashing
e. Insulation
f. Brick
g. Concrete block
h. Plaster

Objective6

a. Three way switch
b. Double pole switch
c. Low voltage wire
d. Horn
e. Fused switch
f. Fluorescent light
g. Single pole switch
h. Switch with pilot light
i. Bell
j. Push button
k. Square recessed light
l. Chime
m. Buzzer
n. Switch for low voltage system
o. Circuit breaker
p. Low voltage master switch
q. Duplex receptacle outlet
r. Round recessed light
s. Lampholder
t. Clock outlet
u. Automatic door switch
v. Weatherproof switch
w. Electric door opener
x. Switch leg indicator
y. Relay equipped lighting outlet
z. Split wired receptacle outlet
aa. Weatherproof duplex outlet
bb. Special circuit
cc. Rectangular recessed light
dd. Fan outlet
ee. Lighting outlet
ff. Four way switch
gg. Single receptacle outlet
hh. Isolated ground receptacle
ii. Junction box
jj. Lampholder with pull switch
kk. Television outlet
ll. Outside telephone
mm. Baseboard heat

Answers to Written Test

Objective 7

a. Lighting panel
b. Generator
c. Controller
d. Power transformer
e. Feeder
f. Switch and fuse
g. Motor
h. Power panel
i. Overcurrent device
j. Instrument

Objective 8

a. 3
b. 7
c. 6
d. 8
e. 9
f. 5
g. 4
h. 2
i. 1

Objective 9

a. Minimum standards
b. Type of equipment
c. Type of installation
d. Special instructions

Objective 10

a. 125
b. 12
c. Square foot
d. Motors, appliances

Objective 11

a. #14
b. #14
c. #14
d. #10
e. #8

Objective 12

a, d

Objective 13

All are correct.

Objective 14

a. 5
b. 4
c. 2
d. 1
e. 6
f. 3

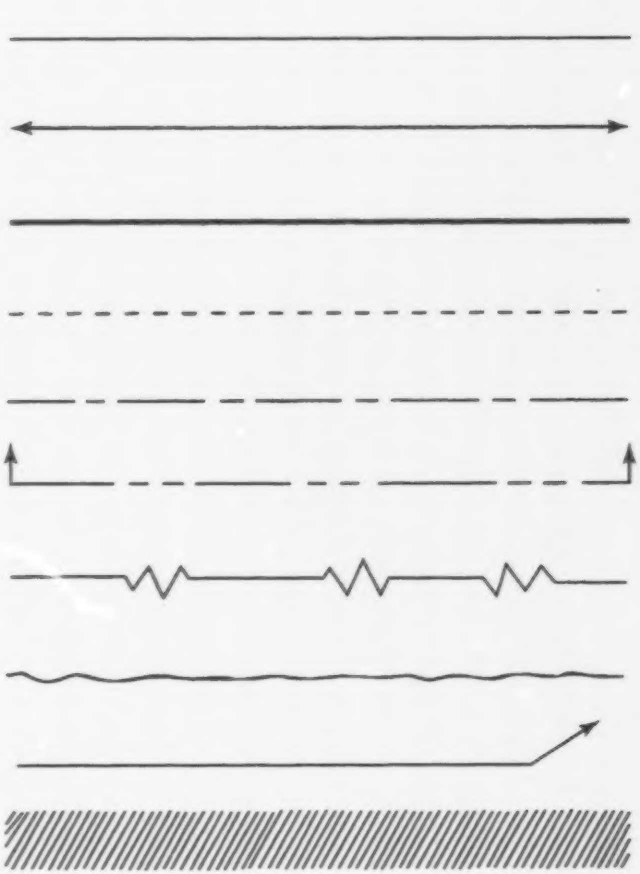
Teacher Supplement 1—Participants at a Construction Site

Note: This supplement is intended to be used in conjunction with the Focus Assignment

Although a case can be made for other occupations on the list, the primary participants in a construction project are:

1. **Architects** design the project (sometimes oversee the project)
2. **Engineers** oversee the project (sometimes design the project or portions of it)
3. **Bankers** provide financing for the project
4. **Owners** own the land and may manage the financing of the project
5. **Construction Workers** do the various tasks required to construct the work

Alphabet of Lines



Object Line

Dimension Line

Extension Line

Hidden Line

Center Line

Cutting Plane

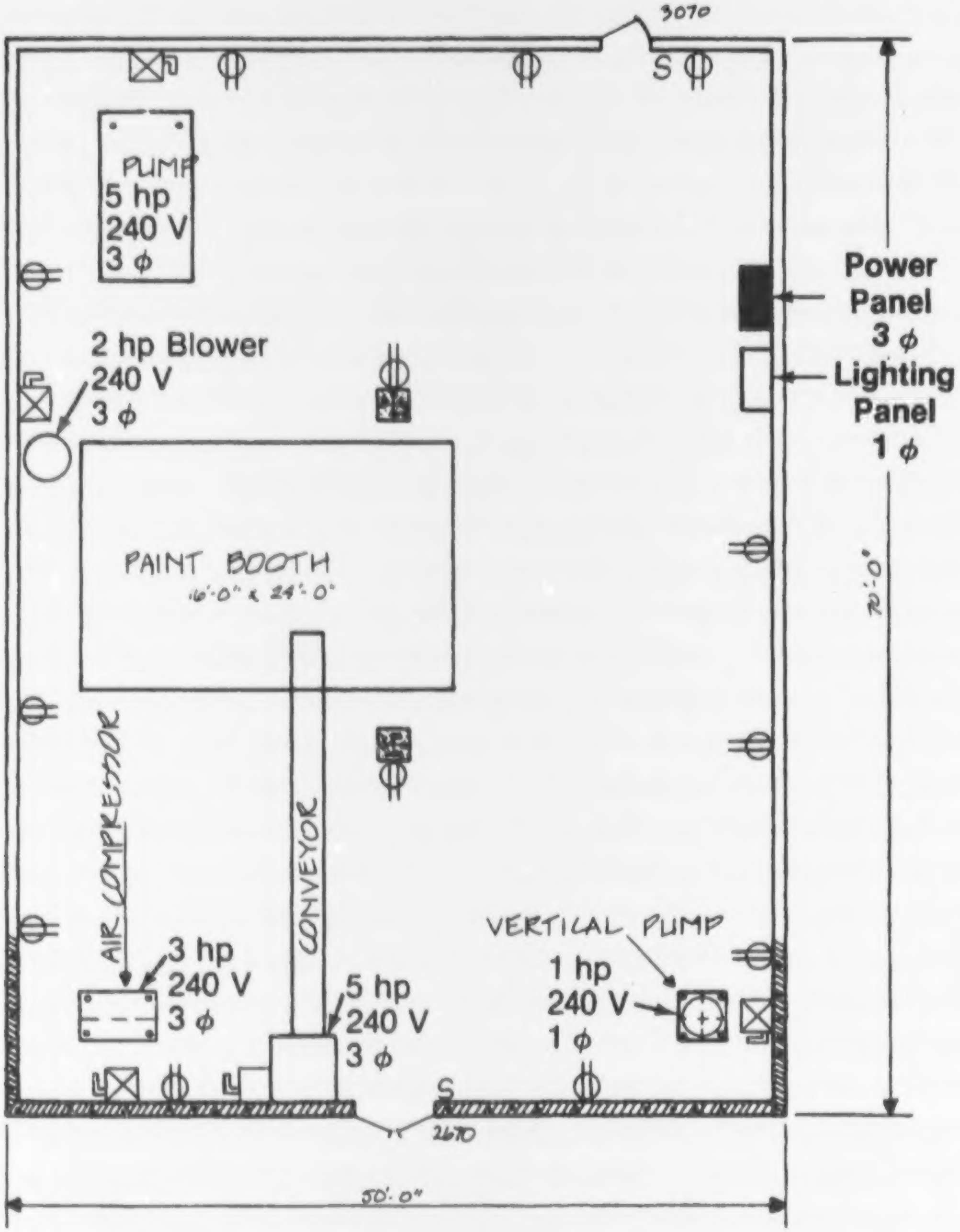
Break Line (Long)

Break Line (Short)

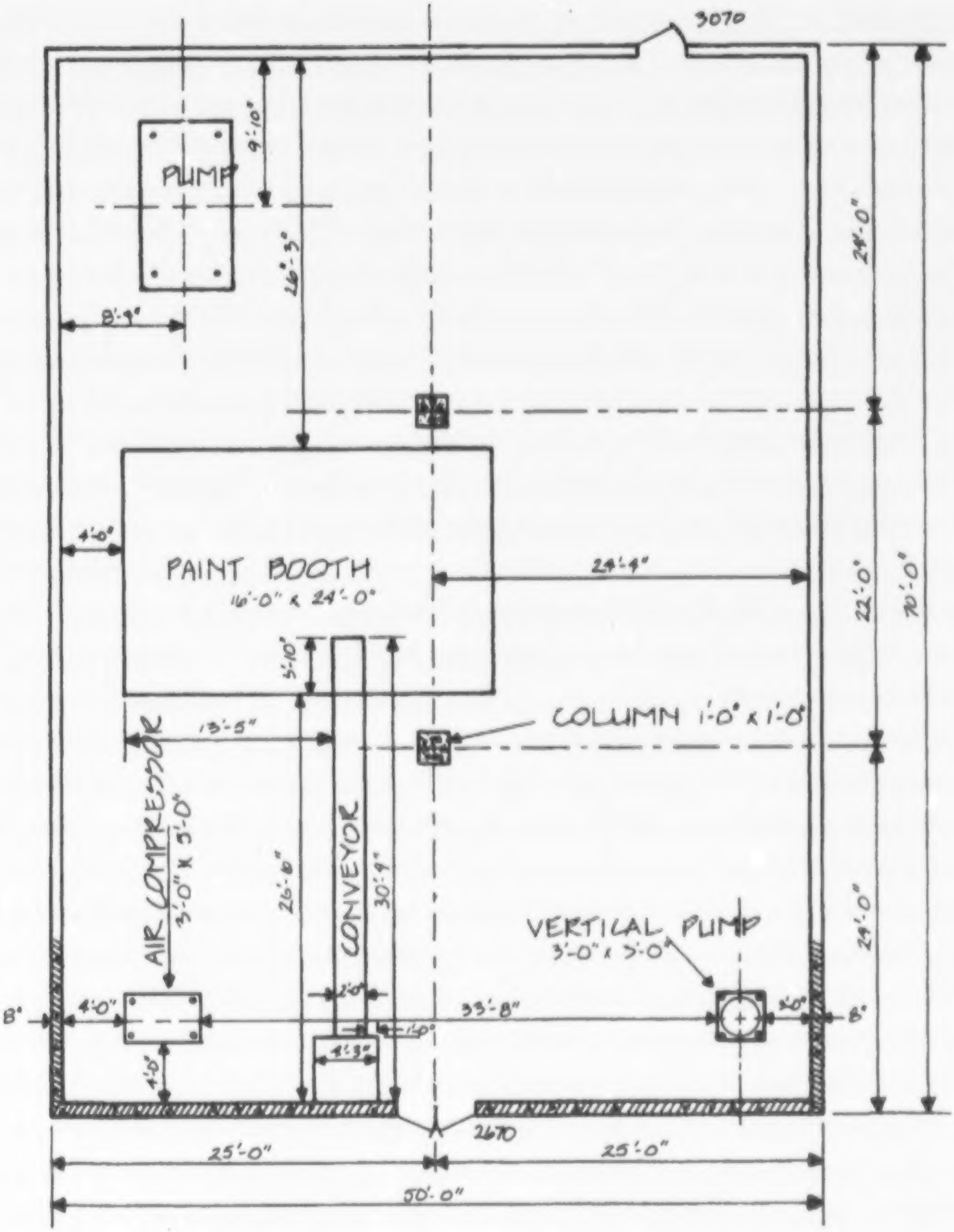
Leader

Section Lines

Electrical Floor Plan

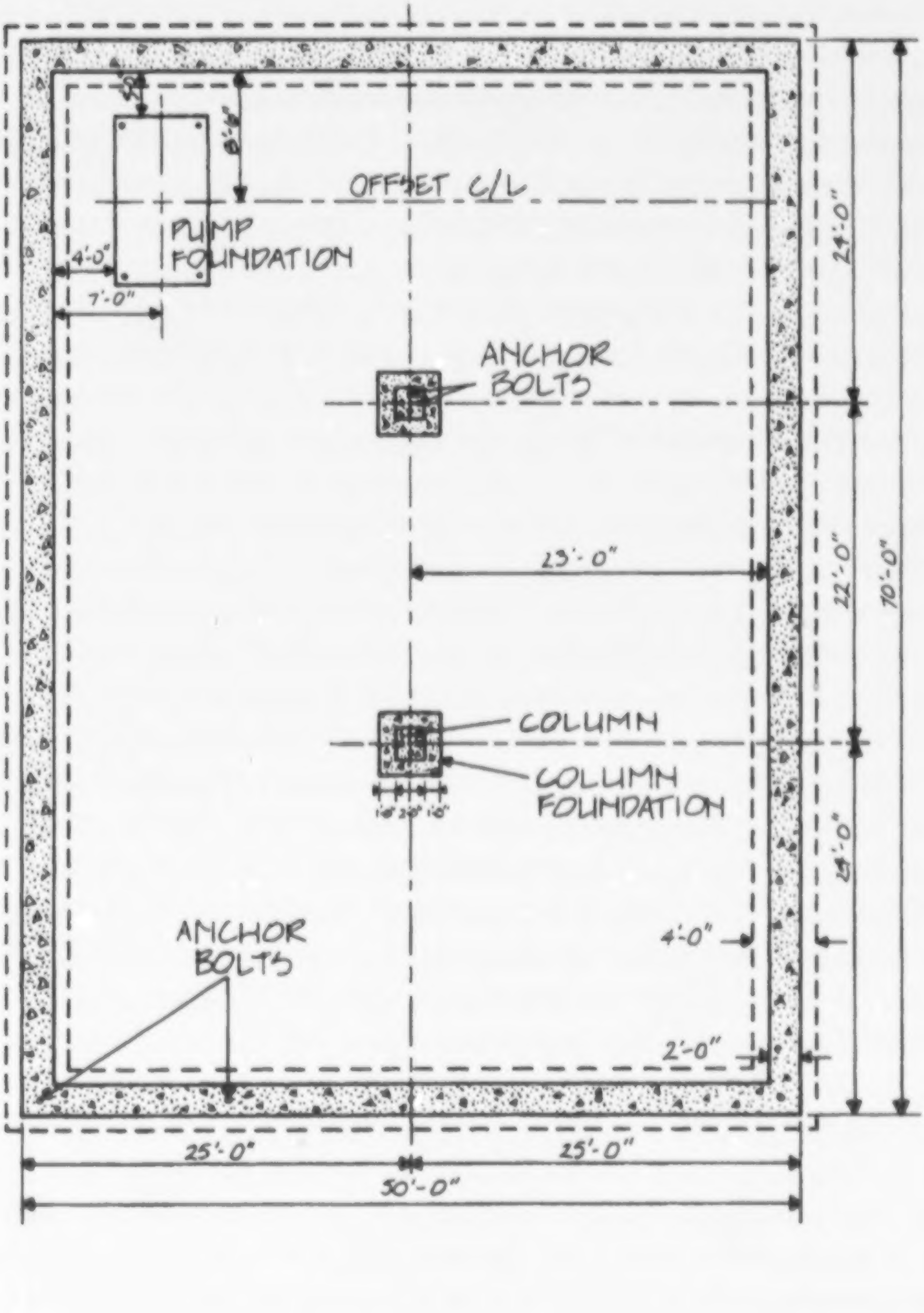

3070
S
PUMP
5 hp
240 V
3 φ
2 hp Blower
240 V
3 φ
Power
Panel
3 φ
Lighting
Panel
1 φ
PAINT BOOTH
16'-0" x 24'-0"
70'-0"
AIR COMPRESSOR
CONVEYOR
3 hp
240 V
3 φ
5 hp
240 V
3 φ
VERTICAL PUMP
1 hp
240 V
1 φ
S
2670
50'-0"

Floor Plan


3070
9'-10"
PUMP
26'-3"
8'-9"
24'-0"
4'-0"
PAINT BOOTH
16'-0" x 24'-0"
24'-4"
22'-0"
70'-0"
3'-10"
COLUMN 1'-0" x 1'-0"
13'-5"
AIR COMPRESSOR
3'-0" x 3'-0"
26'-6"
CONVEYOR
30'-9"
VERTICAL PUMP
3'-0" x 3'-0"
24'-0"
8"
4'-0"
2'-0"
33'-8"
3'-0"
8"
1'-0"
4'-3"
4'-0"
2670
25'-0"
25'-0"
50'-0"

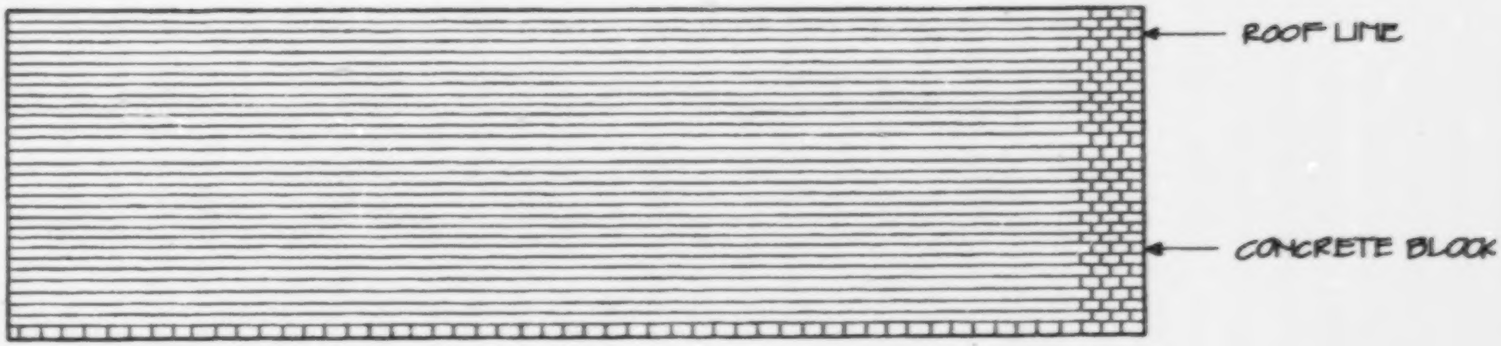
TM 3

Foundation Plan

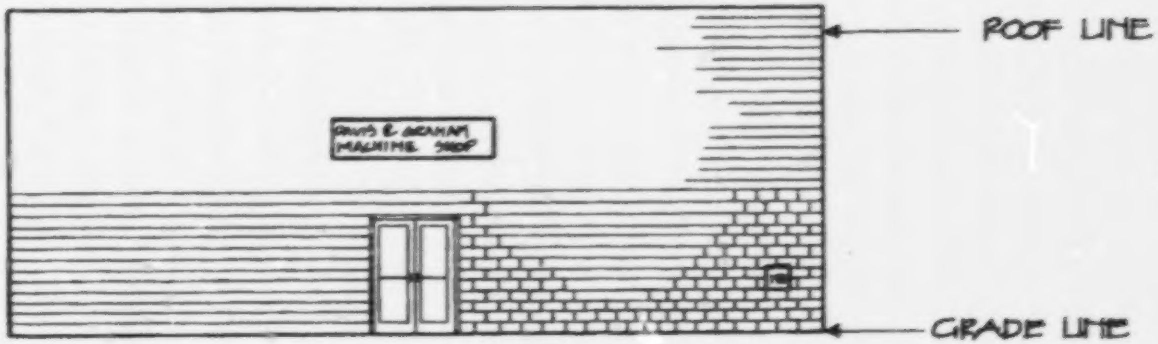

8'-6"
OFFSET C/L
PUMP FOUNDATION
4'-0"
7'-0"
ANCHOR BOLTS
24'-0"
25'-0"
22'-0"
70'-0"
COLUMN
COLUMN FOUNDATION
1'0" 2'0" 1'0"
24'-0"
ANCHOR BOLTS
4'-0"
2'-0"
25'-0"
25'-0"
50'-0"

TM 4

Elevations

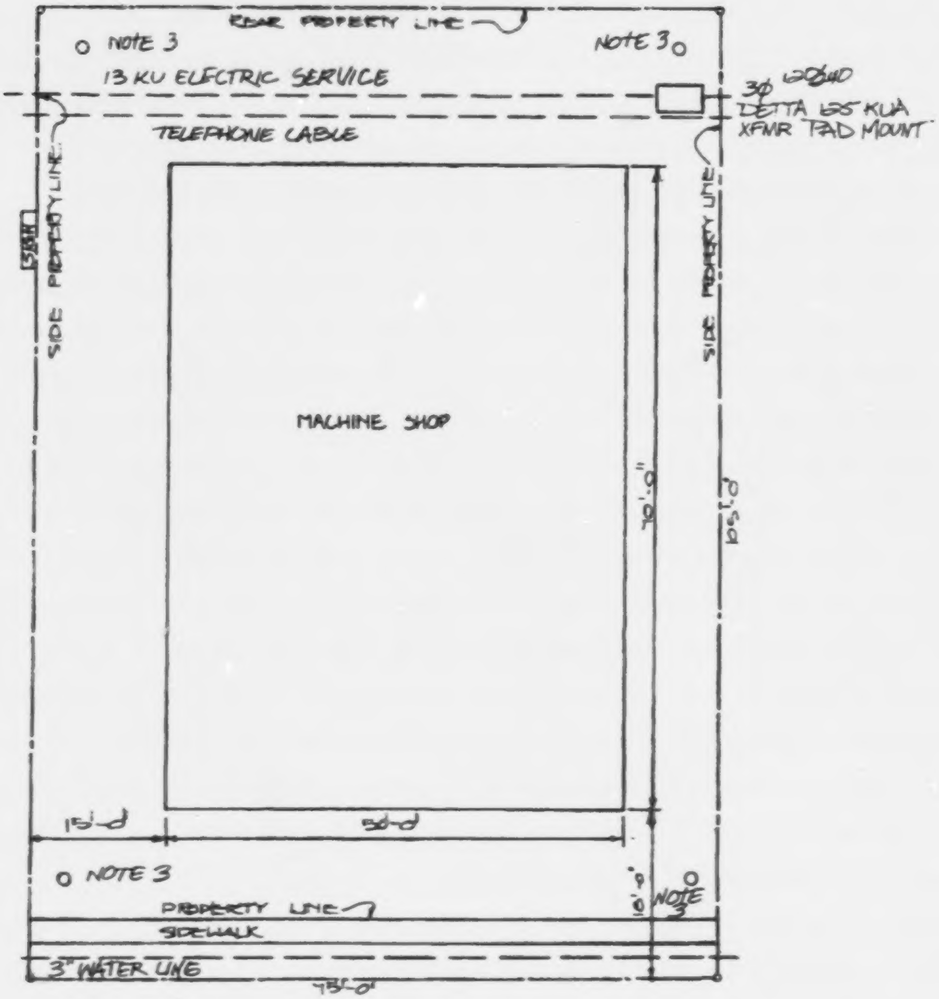

ROOF LINE
CONCRETE BLOCK

WEST ELEVATION


DAVIS & GRAHAM
MACHINE SHOP
ROOF LINE
GRADE LINE

SOUTH ELEVATION

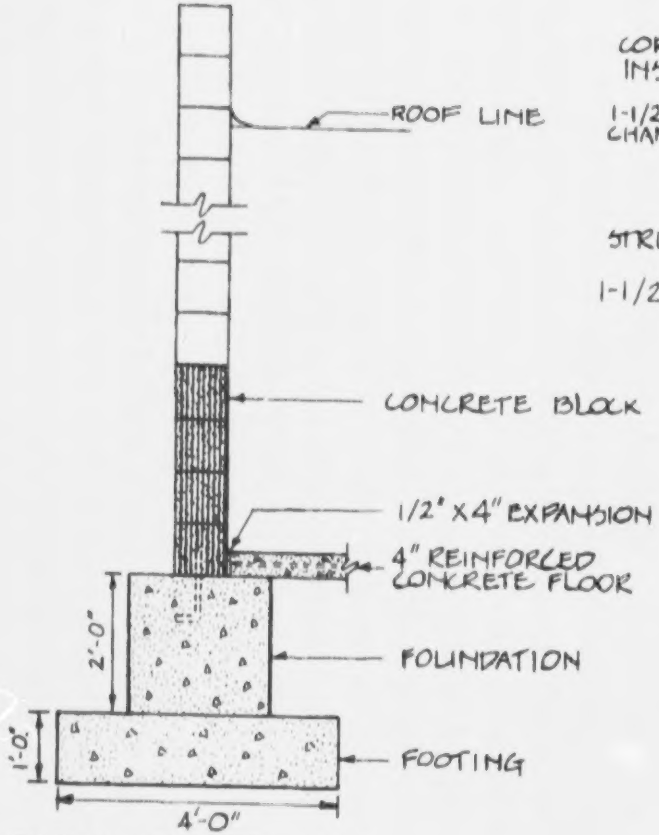
Plot Plan


REAR PROPERTY LINE
NOTE 3
NOTE 3
13 KV ELECTRIC SERVICE
3φ 120/240
DELTA 125 KVA
XFMR PAD MOUNT
TELEPHONE CABLE
SIDE PROPERTY LINE
SIDE PROPERTY LINE
MACHINE SHOP
70'-0"
105'-0"
15'-0"
50'-0"
NOTE 3
PROPERTY LINE
10'-0"
NOTE 3
SIDEWALK
3" WATER LINE
75'-0"

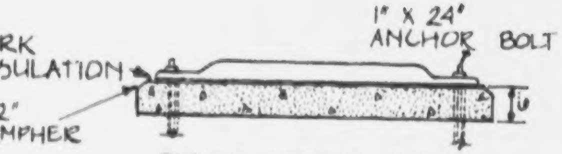
Note 3: 30′ steel pole with one [illegible]0W HPS flood.

TM 6

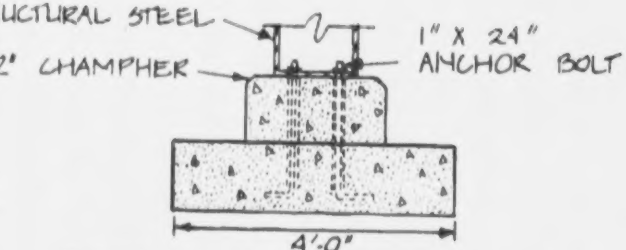
Details


ROOF LINE
CONCRETE BLOCK
1/2" X 4" EXPANSION
4" REINFORCED CONCRETE FLOOR
FOUNDATION
FOOTING
2'-0"
1'-0"
4'-0"

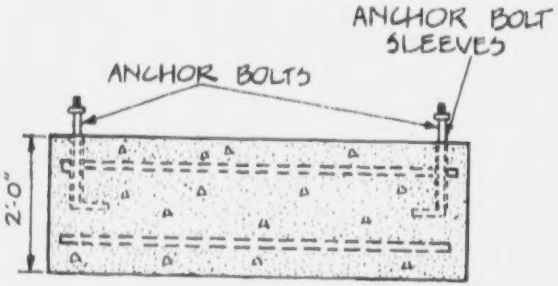
TYPICAL EXTERIOR WALL


CORK INSULATION
1-1/2" CHAMPHER
1" X 24" ANCHOR BOLT
6

TYPICAL MACHINE BASE


STRUCTURAL STEEL
1-1/2" CHAMPHER
1" X 24" ANCHOR BOLT
4'-0"

TYPICAL COLUMN FOUNDATION AND PIER


ANCHOR BOLTS
ANCHOR BOLT SLEEVES
2'-0"

TYPICAL MACHINE FOUNDATION

Unit 2 Tools and Equipment

Unit Contents

Teacher Page

Teacher Components

Suggested Activities 2–3
Written Test 2–7
Answers to Written Test 2–17

Student Page

Student Components

Objective Sheet 2–3
Information Sheet 2–5

* Focus Assignment

Describe a Tool, and Suggest Changes to Increase Its Efficiency 23

* Job Sheets

1—Bend, Cut, Ream, and Thread One-Half-Inch Rigid Metal Conduit 25
2—Bend EMT Stub-Ups 27
3—Make Back-To-Back Bends on One-Half-Inch EMT 31
4—Make Offset Bends on One-Half-Inch EMT 35
5—Bend and Install One-Half-Inch EMT 39
6—Bend a Three-Point Saddle on One-Half-Inch EMT 43
7—Bend a Four-Point Saddle on One-Half-Inch EMT 47
8—Cut, Ream, Offset, and Install Connectors on One-Half-Inch PVC 51

* Focus Assignment and Job Sheets are located in Student Workbook 1.

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make copies of any teacher supplements that will be provided for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Have students complete the focus assignment to introduce topics presented in unit of instruction.

Suggested Activities

- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheets. Review with students the criteria for evaluation of these activities.
- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Have local equipment company demonstrate excavation equipment.
- Take a tour of a factory to look at bends on piping. Allow for student comments and questions.
- Have supply house bring different kinds of tools and equipment to demonstrate. Conduct a question and answer period following the demonstration.
- Review safety rules relating to proper use of equipment. Ask students to write safety rules in their own words to reinforce learning.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the assignment sheets. Rate the student using the criteria listed on each assignment sheet. See Answers to Assignment Sheets for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.
- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

Suggested Activities

Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

Sample A

4—**Skilled**—Can perform job with no additional training.
3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
1—**Unskilled**—Is familiar with process, but is unable to perform job.
0—**No exposure**—No information or practice provided during training program.

Sample B

Yes—Can perform job with no additional training.
No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Greenlee tool catalog. Rockford, IL: Greenlee Tool Company.
- Kaltwasser, Stan and Gary Flowers. *Commercial and Industrial Wiring*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.
- Taylor, Mark. *Residential Wiring*. Revised. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1983.
- Teague, Cash and Garner Pewewardy. *Industrial Electricity: In-Plant Distribution*. Stillwater, OK: Oklahoma Curriculum and Instructional Materials Center, 1984.

Suggested Supplemental Resources

Print Media

- *2002 NEC Analysis of Changes*. Quincy, MA: National Fire Protection Association, 2001.

  Provides a detailed view of the most important changes in the 2002 NEC
- *NEC 2002 Handbook*. Quincy, MA: National Fire Protection Association, 2001.

Contains complete Code text plus commentary, photos, and full-color graphics

The publication(s) listed above can be ordered from:

National Fire Protection Association
1 Batterymarch Park
Quincy, MA 02269-9101
1-800-344-3555
www.nfpa.org

- Early, Mark W., et al. *Illustrated Changes in the National Electrical Code*. Delmar Publishers, Inc. 2002.

  Provides a detailed view of the most important changes in the 2002 NEC

- Herman, Stephen L. *Electrician's Technical Reference: Industrial Electronics*. Delmar Publishers, Inc. 1999.
- Loyd, Richard. *Electrical Raceways and Other Wiring Methods,* 4th ed. Delmar Publishers, Inc. 2002.
- Loyd, Richard. *Electrician's Technical Reference: Wiring Methods*. Delmar Publishers, Inc. 1999.
- Miller, Chris. *Illustrated Guide to the National Electrical Code,* 2nd ed. Delmar Publishers, Inc. 2002.

  Conveniently groups Code requirements according to type of occupancy, and contains 600 illustrations

- Mullin, Ray and Robert Smith. *Electrical Wiring Commercial*, 11th ed. Delmar Publishers, Inc. 2002.
- O'Riley, Ronald. *Electrical Grounding,* 6th ed. Delmar Publishers, Inc. 2002.
- Simpson, James G. *Common Sense Conduit Bending and Cable Tray Techniques*. Delmar Publishers, Inc. 1996.
- Smith, Robert and Stephen Herman. *Electrical Wiring Industrial*, 11th ed. Delmar Publishers, Inc. 2002.
- Surbrook, Truman and Jonathan Althouse. *Interpreting the National Electrical Code,* 6th ed. Delmar Publishers, Inc. 2002.

  Offer practical examples to illustrate how articles in the Code are applied

- Titus, Patricia A., et al. *Illustrated Dictionary for Electrical Workers,* 2nd ed. Delmar Publishers, Inc. 2002.

Written Test

Name ____

Date ________________________________ Score__________

Objective 1

Match the terms related to tools and equipment with their definitions. Write the correct numbers in the blanks. Definitions continue on the next page.

1. Backhoe
2. Bender
3. Cable bender
4. Cable cutters
5. Cutting tools
6. Fish tape
7. Hammer drill
8. Jet line
9. Knockout cutter
10. Pulling equipment
11. Pulling lube
12. Pulling sleeve
13. Powder actuated device
14. Strippers
15. Threading tools
16. Trencher

_____ a. Machine used to dig trenches

_____ b. Machine used to dig ditches on construction sites

_____ c. Used to bore through concrete

_____ d. Used to cut conduit for electrical installations

_____ e. Used to bend large conductors

_____ f. Used to thread pipe so electrical fittings may be attached to conduit

_____ g. Used to remove insulation from conductors

_____ h. Used to cut holes, slots, and cuts in electrical boxes and studs

_____ i. Used to bend pipe used in electrical trades

_____ j. Used to pull multiple and large conductors through a conduit

_____ k. Attaches around the end of conductors so they may be pulled through a conduit

_____ l. Uses charges that shoot studs and tie downs into concrete, metal, and wood

_____ m. Wax-based product that allows the conductors to pass through the conduit causing less friction

_____ n. Used to cut conductors

_____ o. Long tape of steel, nylon, or other material used to push or pull conductors into a raceway

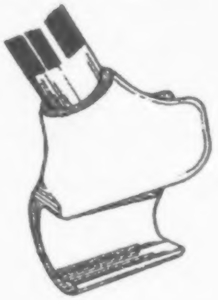
_____ p. Line sucked or blown through a conduit by positive or negative pressure so a rope or tape can be pulled through a conduit.

Written Test

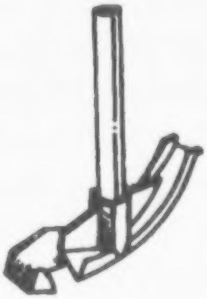
Objective 2

Identify the following types of:

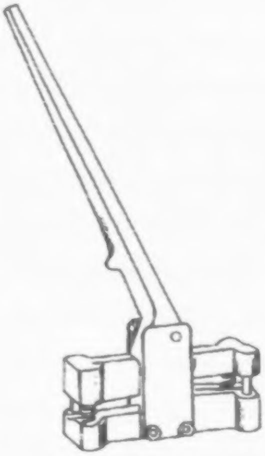
a. Conduit benders.



1. ____________________

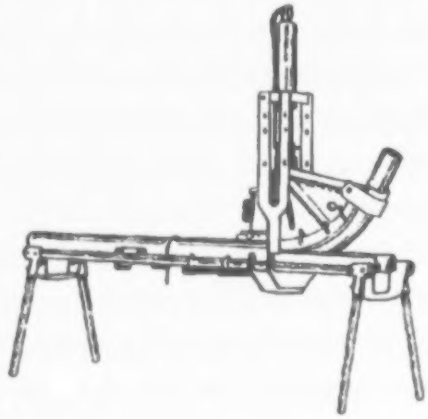


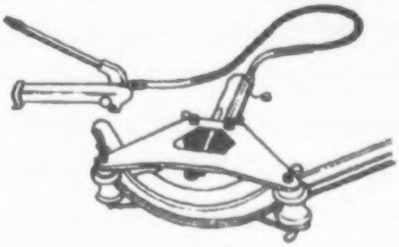
2. ____________________



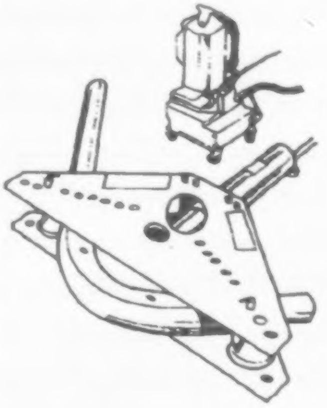
3. ____________________

b. Hydraulic conduit benders



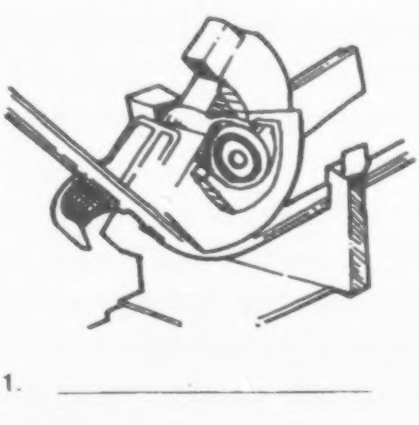


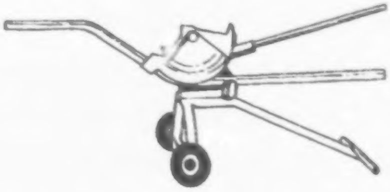
1. ____________________ 2. ____________________



3. ____________________

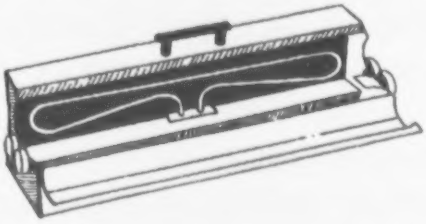
c. Mechanical conduit benders

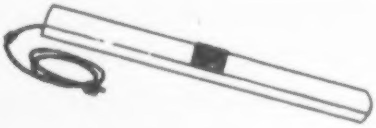




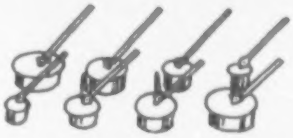
1. ____________________ 2. ____________________

d. PVC bending equipment





1. ____________________ 2. ____________________

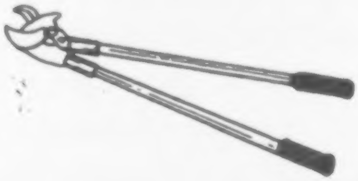


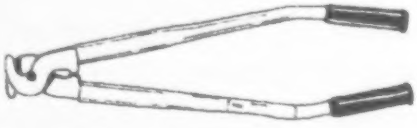
3. ____________________

Objective 3

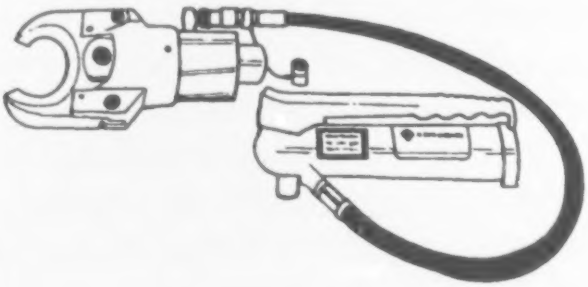
Identify the wire termination tools shown below.

a. Cable cutters



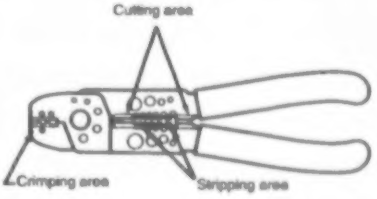


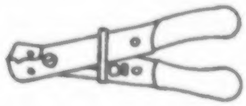
1. ____________________ 2. ____________________



3. ____________________

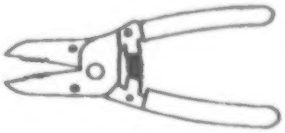
b. Wire strippers and crimpers

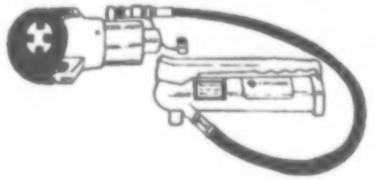

Cutting area
Crimping area
Stripping area



1. ____________________

2. ____________________

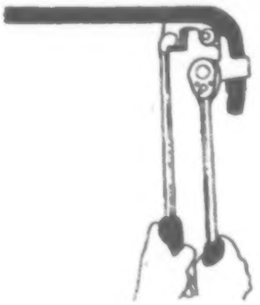


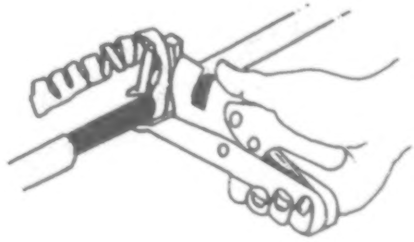


3. ____________________

4. ____________________

c. Cable stripper and bender





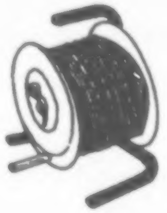
1. ____________________

2. ____________________

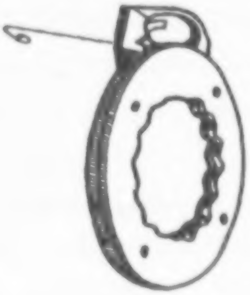
Written Test

Objective 4

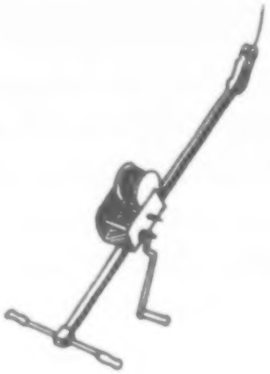
Identify the wire and cable pulling equipment shown below.



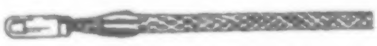
a. ______________________



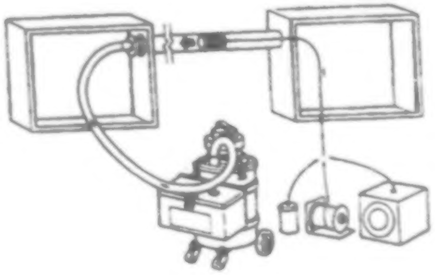
b. ______________________



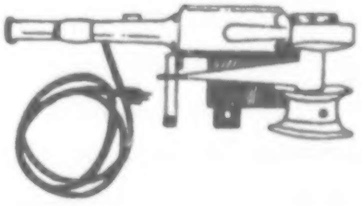
c. ______________________



d. ______________________



e. ______________________

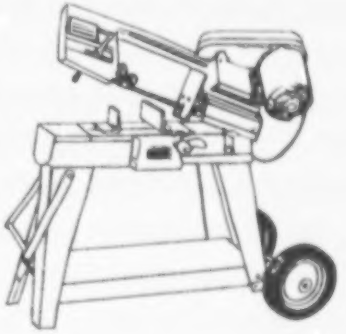


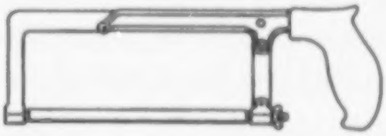
f. ______________________

Objective 5

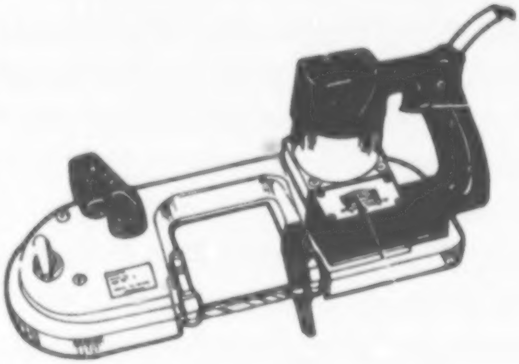
Identify the conduit cutting and threading tools shown below.

a. Cutting tools



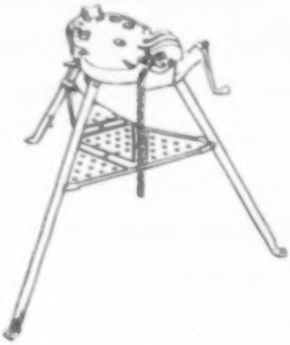


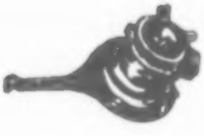
1. ____________________ 2. ____________________



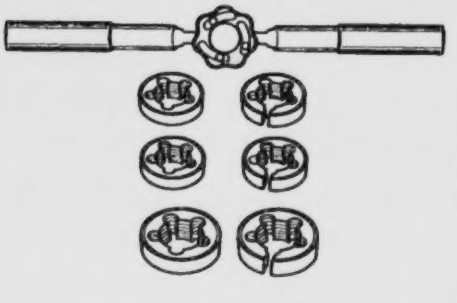
3. ____________________

b. Threading tools

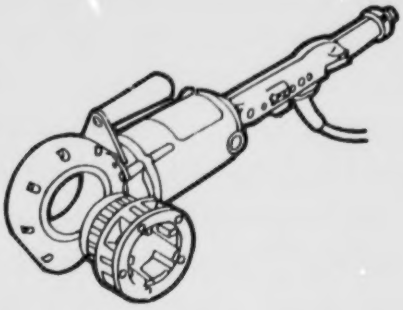




1. ____________________ 2. ____________________



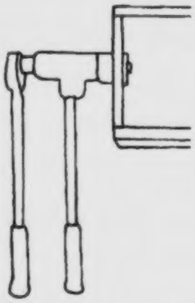
3. ______________________



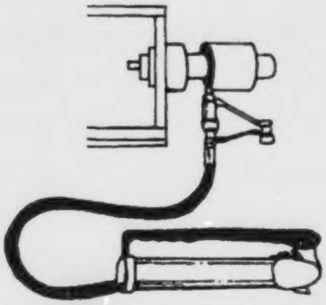
4. ______________________

Objective 6

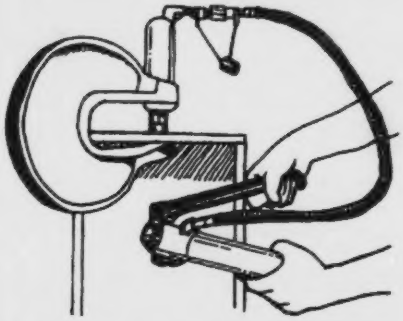
Identify the following knockout cutters.



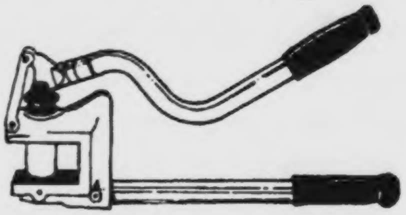
a. ______________________



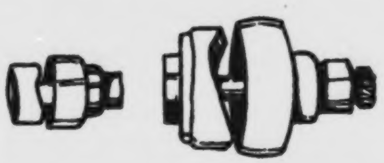
b. ______________________



c. ______________________



d. ______________________



e. ______________________

Objective 7

List two power actuated tools used in the electrical trade.

a. ____________________

b. ____________________

Objective 8

List two types of excavation equipment.

a. ____________________

b. ____________________

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a. 16
b. 1
c. 7
d. 5
e. 3
f. 15
g. 14
h. 9
i. 2
j. 10
k. 12
l. 13
m. 11
n. 4
o. 6
p. 8

Objective 2

a. (1) Hickey bender
   (2) EMT bender
   (3) One shot offset

b. (1) Table bender
   (2) Manual hydraulic bender
   (3) Rigid bender

c. (1) Rigid bender
   (2) EMT bender

d. (1) Electric PVC heater
   (2) PVC blanket
   (3) PVC pipe plugs

Objective 3

a. (1) Ratchet cutters
   (2) Manual cutters
   (3) Hydraulic cutters

b. (1) Combination tool
   (2) Adjustable wire strippers
   (3) Stripper/cutter
   (4) Hydraulic crimper

c. (1) Cable bender
   (2) Cable stripper

Objective 4

a. Pulling rope
b. Fish tape
c. Manual puller
d. Pulling sleeve
e. Jet line
f. Electric puller

Objective 5

a. (1) Band saw
   (2) Hacksaw
   (3) Portable band saw

b. (1) Pipe stand
   (2) Electric die set
   (3) Manual die set
   (4) Electric portable threader

Answers to Written Test

Objective 6

a. Ratchet K.O.
b. Hydraulic K.O.
c. C-punch K.O.
d. Stud punch
e. Manual K.O.

Objective 7

a. Hammer drill
b. Powder actuated device

Objective 8

a. Trencher
b. Backhoe

Unit 3 Service

Unit Contents

Teacher Components

Teacher Page

Suggested Activities 3–3
Written Test 3–7
Answers to Written Test 3–11

Transparency Masters

1—Installing a Grounding Rod 3–13
2—Potential Transformer 3–15
3—Current Transformer 3–17

Student Components

Student Page

Objective Sheet 3–3
Information Sheet 3–5

* Job Sheets

1—Install an Overhead Raceway with Service Entrance Conductors to a Meter Base 53
2—Connect a Meter Base Assembly to a Load Center or Panel 57

* Job Sheets are located in Student Workbook 1.

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make copies of any teacher supplements that will be provided for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

TM 1—Installing a Grounding Rod (Objective 5)
TM 2—Potential Transformer (Objective 6)
TM 3—Current Transformer (Objective 6)

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.

Suggested Activities

- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Ask students to name the power company that supplies electricity to their homes. Lead a discussion on the role of power companies, and where their responsibility begins and ends (generating plant–meter).
- Invite a local power company representative to discuss the uses of emergency and standby equipment and *NEC* regulations dealing with services. Have students practice looking up pertinent *NEC* articles.
- Take students on a field trip to a power company. Encourage students to ask questions regarding the plant operation.
- Have a supply house representative demonstrate the different devices for services.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

  Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Suggested Activities

Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

Sample A

4—**Skilled**—Can perform job with no additional training.
3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
1—**Unskilled**—Is familiar with process, but is unable to perform job.
0—**No exposure**—No information or practice provided during training program.

Sample B

Yes—Can perform job with no additional training.
No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Kaltwasser, Stan and Gary Flowers. *Commercial and Industrial Wiring.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.
- *National Electrical Code, 2002.* Quincy, MA: National Fire Protection Association, 2001.
- *National Electrical Code 1999.* Quincy, MA: National Fire Protection Association, 1998.
- *National Electrical Code 1993.* Quincy, MA: National Fire Protection Association, 1992.
- Stallcup, James G. *Designing Electrical Systems Based on the 1990 NEC.* Alsip, IL: American Technical Publishers, Inc., 1990.

Suggested Supplemental Resources

Print Media

- *2002 NEC Analysis of Changes.* Quincy, MA: National Fire Protection Association, 2001.

  Provides a detailed view of the most important changes in the 2002 NEC

- *NEC 2002 Handbook.* Quincy, MA: National Fire Protection Association, 2001.

  Contains complete Code text plus commentary, photos, and full-color graphics

Suggested Activities

The publication(s) listed above can be ordered from:

National Fire Protection Association
1 Batterymarch Park
Quincy, MA 02269-9101
1-800-344-3555
www.nfpa.org

- Early, Mark W., et al. *Illustrated Changes in the National Electrical Code.* Delmar Publishers, Inc. 2002.

  Provides a detailed view of the most important changes in the 2002 NEC

- Herman, Stephen L. *Electrician's Technical Reference: Transformers.* Delmar Publishers, Inc. 1999.

  Focuses on the theoretical and practical aspects of single- and three-phase transformers and connections

- Loyd, Richard. *Electrical Raceways and Other Wiring Methods,* 4th ed. Delmar Publishers, Inc. 2002.

- Miller, Chris. *Illustrated Guide to the National Electrical Code,* 2nd ed. Delmar Publishers, Inc. 2002.

  Conveniently groups Code requirements according to type of occupancy, and contains 600 illustrations

- Mullin, Ray and Robert Smith. *Electrical Wiring Commercial,* 11th ed. Delmar Publishers, Inc. 2002.

- O'Riley, Ronald. *Electrical Grounding,* 6th ed. Delmar Publishers, Inc. 2002.

- Simpson, James G. *Common Sense Conduit Bending and Cable Tray Techniques.* Delmar Publishers, Inc. 1996.

  Geared especially for students

- Smith, Robert and Stephen Herman. *Electrical Wiring Industrial,* 11th ed. Delmar Publishers, Inc. 2002.

- Surbrook, Truman and Jonathan Althouse. *Interpreting the National Electrical Code,* 6th ed. Delmar Publishers, Inc. 2002.

  Offer practical examples to illustrate how articles in the Code are applied

- Titus, Patricia A., et al. *Illustrated Dictionary for Electrical Workers,* 2nd ed. Delmar Publishers, Inc. 2002.

Written Test

Name ______________________________

Date ______________________ Score __________

Objective 1

Match the terms related to service with their definitions. Write the correct numbers in the blanks.

1. CT
2. Disconnects
3. Equipment grounding conductor
4. Ground
5. Grounded
6. Grounded conductor
7. Grounding electrode conductor
8. PT
9. Service
10. Service drop
11. Service panel
12. Switch board

_____ a. Potential transformer

_____ b. System or circuit conductor that is intentionally grounded

_____ c. Device used for breaking a circuit which may be fused or unfused

_____ d. Any good conductor that is connected to a common chassis with zero relative voltage

_____ e. Current transformer

_____ f. Connected to the earth or to some conducting body that serves in place of the earth

_____ g. Where power is metered or is first attached to the structure

_____ h. Main control panel where voltage and current are distributed to different locations

_____ i. Power conductors coming into building from power company

_____ j. Large single panel, frame or assembly of panels on which are mounted, on the face or back or both, switches, overcurrent, and other protective devices, busses, and usually instruments; generally accessible from the rear as well as the front and intended to be installed in a cabinet

_____ k. Conductor used to connect non-current carrying metal parts of equipment to the system-grounded conductor or grounding-electrode conductor

_____ l. Conductor used to connect grounding electrode to the equipment grounding conductor or to grounding conductor of circuit at service equipment or at source of separately derived system

Written Test

Objective 2

Complete statements concerning *NEC* requirements for drop clearance and laterals by filling in the blanks with the correct answers.

a. There are two basic types of services: ____________________ and ____________________.

b. Overhead services must be a specific size and have a minimum clearance from the finished ____________________.

c. The smallest conductors that can be used on a service are ____________________ copper and ____________________ aluminum.

d. Service drop conductors passing over a roof must be at least ____________________ above the roof.

e. Exception No. 2 allows service drops to pass ____________________ feet above the roof when the roof has a slope of 4 inches (102 mm) in 12 inches (305 mm) and the voltage is not in excess of ____________________ volts.

f. Exception No. 3 allows the service drop to be attached to the service mast when the drop does not pass over 4 feet (1.22m) of roof and the mast is at least ____________________ inches above the roof line.

g. Service drop conductors rated at ____________________ or less have minimum clearances.

h. An underground service lateral must have a conductor size of at least ____________________ copper or ____________________ aluminum.

Objective 3

Select true statements concerning switch boards and disconnects by placing an "X" in the blanks next to the true statements.

_____ a. A switch board is used for breaking the current or voltage from the meter base to the means of disconnection before being allowed to enter branch circuits.

_____ b. Service disconnects are readily accessible for breaking the power entering a building. Only one disconnect may be used on a service.

_____ c. Few service disconnects have overload protection. The disconnect must be large enough to cary the computed load it supplies.

Objective 4 Match the *NEC* exceptions for overcurrent protection devices with their definitions. Write the correct numbers in the blanks.

1. Exception No. 1
2. Exception No. 2
3. Exception No. 3
4. Exception No. 4

_____ a. Two to six CBs or fuses may serve as overcurrent protection devices.

_____ b. If not a standard size, the next higher standard size overcurrent protection device is used.

_____ c. An overcurrent protection device may be overfused to allow motors to attain running speed.

_____ d. An overcurrent protection device must be rated to carry locked-rotor current of fire pump motors.

Objective 5 Complete statements concerning grounding electrodes and ground fault by circling the correct answers.

a. There are four types of electrode grounding systems used in electrical trades. The include (**aluminum, metal**) water pipe, building (**steel, iron**), reinforcing rod (**15 feet, 20 feet**) minimum length, and ground (**rod, ring**).

b. A ground (**is, is not**) required if the power company's secondary system is not efficiently grounded.

Objective 6 Select true statements concerning service entrance devices by placing an "X" in the blanks next to the true statements.

_____ a. A current transformer (CT) steps the voltage down so voltage measuring devices may be used.

_____ b. Conductor sizes of 1/0 or larger comprising each phase to neutral will be permitted to be connected in parallel. This means two conductors are used as one.

_____ c. A potential transformer (PT) is a doughnut type device used in measuring current. These are used in metering large services.

Objective 7 Complete the following statements concerning emergency and standby systems.

a. Separate, derived systems such as a ____________ or ____________ backup are used when the incoming voltage from the power company is interrupted or cut off. These systems are used in ____________, factories, and stores where electricity is a must.

b. An ____________ ____________ ____________ senses voltage loss and automatically switches a system to emergency power.

Objective 8 State the procedure for balancing loads.

____

____

Answers to Written Test

Objective 1

a. 8
b. 6
c. 2
d. 4
e. 1
f. 5
g. 9
h. 11
i. 10
j. 12
k. 3
l. 7

Objective 2

a. Overhead, underground (lateral)
b. Grade
c. #8, #6
d. 8 feet
e. 3 feet, 300
f. 18
g. 600V
h. #8, #6

Objective 3

a

Objective 4

a. 3
b. 2
c. 1
d. 4

Objective 5

a. Metal, steel, 20 feet, ring
b. Is

Objective 6

b

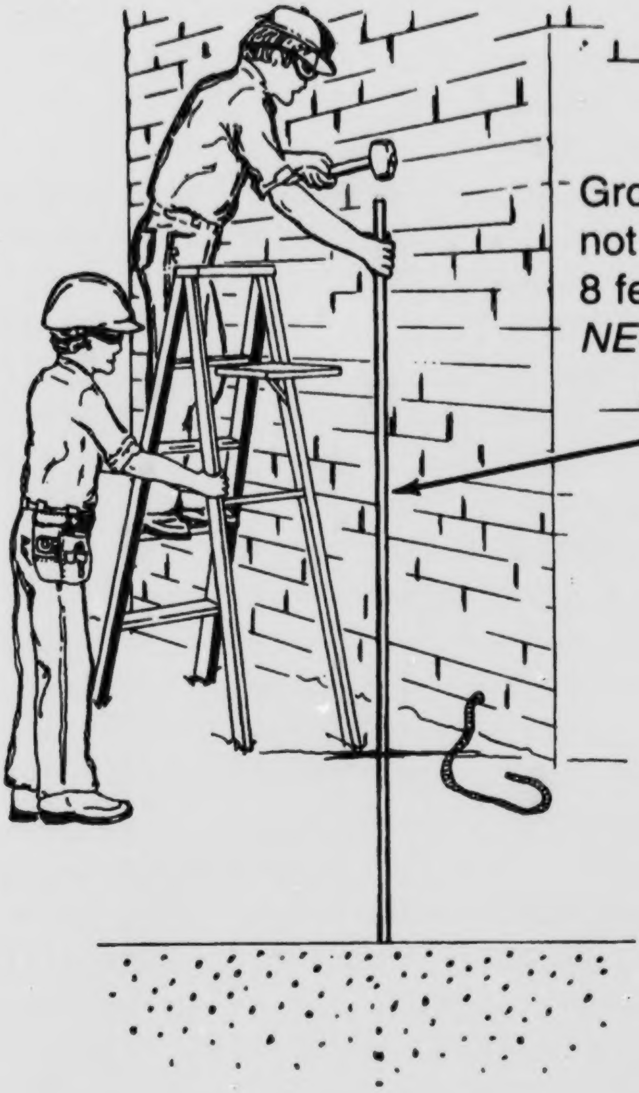
Objective 7

a. Generator, battery, hospitals
b. Automatic transfer switch

Objective 8

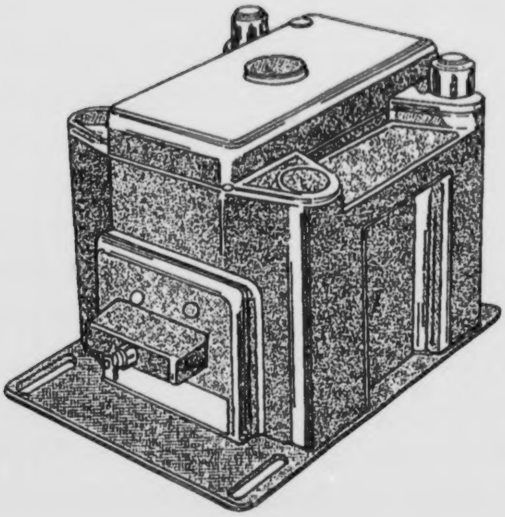
a. When balancing loads on panels, transformers, and switching equipment, an amprobe should be used to determine amperage on each circuit.

Installing a Grounding Rod

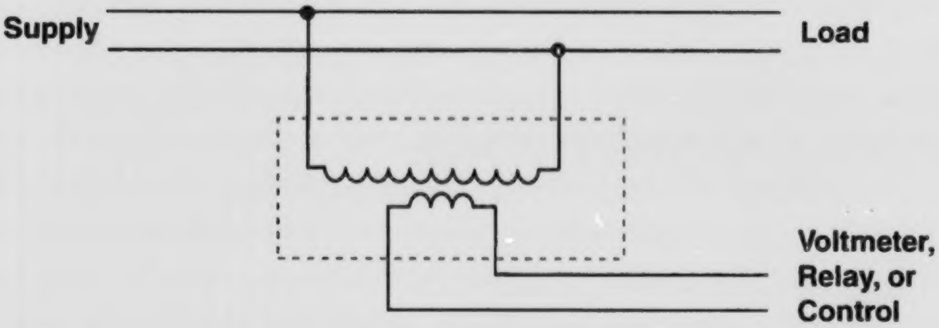


Ground rod must not be less than 8 feet (2.5 m) in length. *NEC* 250.52(A)5

Potential Transformer

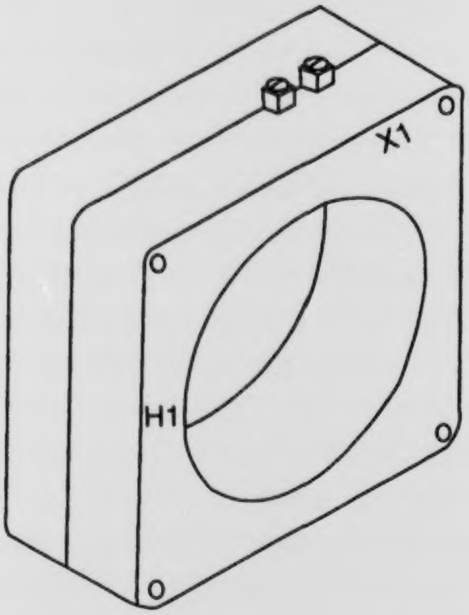


The primary of a Potential Transformer is connected in parallel with the voltage to be measured, relayed, or controlled.

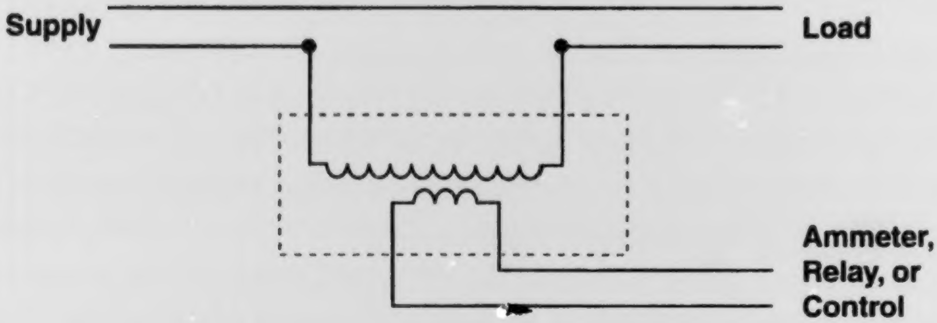

Supply
Load
Voltmeter,
Relay, or
Control

TM 2

Current Transformer



A Current Transformer has its primary connected in series with the source of supply.


Supply
Load
Ammeter,
Relay, or
Control

Unit 4 Transformers

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* Focus Assignment, Assignment Sheets, and Job Sheets are located in Student Workbook 1.

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make copies of any teacher supplements that will be provided for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

  TM 1—Basic Types of Transformers (Objective 2)

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.

Suggested Activities

- Have students complete the focus assignment to introduce topics presented in unit of instruction.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheets. Review with students the criteria for evaluation of these activities.
- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Invite a representative from a transformer winding shop to class to discuss transformer maintenance.
- Have students refer to the *NEC* to locate specific *NEC* requirements pertaining to transformers. Have students list the *NEC* article number and briefly describe the indicated requirements.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the assignment sheets. Rate the student using the criteria listed on each assignment sheet. See Answers to Assignment Sheets for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.
- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

Sample A

4—**Skilled**—Can perform job with no additional training.
3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
1—**Unskilled**—Is familiar with process, but is unable to perform job.
0—**No exposure**—No information or practice provided during training program.

Sample B

Yes—Can perform job with no additional training.
No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Kaltwasser, Stan and Gary Flowers. *Commercial and Industrial Wiring.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.
- *National Electrical Code, 2002.* Quincy, MA: National Fire Protection Association, 2001.
- *National Electrical Code 1999.* Quincy, MA: National Fire Protection Association, 1998.
- *National Electrical Code 1993.* Quincy, MA: National Fire Protection Association, 1992.
- Stallcup, James G. *Designing Electrical Systems Based on the the 1990 NEC.* Alsip, IL: American Technical Publishers, Inc., 1990.
- Turner, J. Howard. *Understanding Electricity and Electrical Terms.* Athens, GA: American Association for Vocational Instructional Materials, 1974.

Suggested Activities

Suggested Supplemental Resources

Print Media

- *2002 NEC Analysis of Changes.* Quincy, MA: National Fire Protection Association, 2001.

  Provides a detailed view of the most important changes in the 2002 NEC

- *NEC 2002 Handbook.* Quincy, MA: National Fire Protection Association, 2001.

  Contains complete Code text plus commentary, photos, and full-color graphics

  The publication(s) listed above can be ordered from:

  National Fire Protection Association
  1 Batterymarch Park
  Quincy, MA 02269-9101
  1-800-344-3555
  www.nfpa.org

- Early, Mark W., et al. *Illustrated Changes in the National Electrical Code.* Delmar Publishers, Inc. 2002.

  Provides a detailed view of the most important changes in the 2002 NEC

- Herman, Stephen L. *Electrician's Technical Reference: Industrial Electronics.* Delmar Publishers, Inc. 1999.

- Herman, Stephen L. *Electrician's Technical Reference: Transformers.* Delmar Publishers, Inc. 1999.

  Focuses on the theoretical and practical aspects of single- and three-phase transformers and connections

- Loyd, Richard. *Electrical Raceways and Other Wiring Methods,* 4th ed. Delmar Publishers, Inc. 2002.

- Miller, Chris. *Illustrated Guide to the National Electrical Code,* 2nd ed. Delmar Publishers, Inc. 2002.

  Conveniently groups Code requirements according to type of occupancy, and contains 600 illustrations

- Mullin, Ray and Robert Smith. *Electrical Wiring Commercial,* 11th ed. Delmar Publishers, Inc. 2002.

- O'Riley, Ronald. *Electrical Grounding,* 6th ed. Delmar Publishers, Inc. 2002.

- Smith, Robert and Stephen Herman. *Electrical Wiring Industrial*, 11th ed. Delmar Publishers, Inc. 2002.
- Surbrook, Truman and Jonathan Althouse. *Interpreting the National Electrical Code*, 6th ed. Delmar Publishers, Inc. 2002.

  Offer practical examples to illustrate how articles in the Code are applied
- Titus, Patricia A., et al. *Illustrated Dictionary for Electrical Workers*, 2nd ed. Delmar Publishers, Inc. 2002.

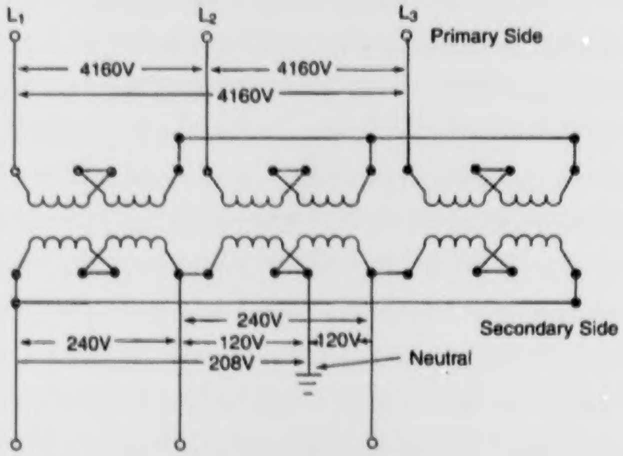
The publication(s) listed above can be ordered from:

Thompson Learning
Attn: Order Fulfillment
P.O. Box 6904
Florence, KY 41022
1-800-477-3692
www.delmar.com

Answers to Assignment Sheets

Assignment Sheet 1

Draw a Three-Phase Wye-Delta Transformer


L1
L2
L3
Primary Side
4160V
4160V
4160V
240V
240V
120V
120V
208V
Neutral
Secondary Side

Assignment Sheet 2

Locate and List Two Exceptions on Transformer Room Construction for Dry Type Transformers

a. *NEC* Article 450.21(B), Exception No. 1
b. *NEC* Article 450.21(B), Exception No. 2

Assignment Sheet 3

Locate and List Two Exceptions Concerning Oil-Insulted Transformers

a.-b. *NEC* Article 450.26, Exceptions No. 1 through No. 5 (any two)

Assignment Sheet 4

Given Amperes, Calculate KVA on a Three-Phase System

a. 50 (60.2A x 480V x 1.732)
b. 100 (120A x 480V x 1.732)
c. 200 (241A x 480V x 1.732)
d. 500 (602A x 480V x 1.732)

Written Test

Name ______________________________

Date ______________________ Score __________

Objective 1

Match the terms related to transformers with their definitions. Write the correct numbers in the blanks.

1. Ambient temperature
2. Buck and boost transformer
3. Isolating transformer
4. Transformer vault

_____ a. A transformer that increases or decreases voltage

_____ b. Insulates the primary circuit from the secondary circuit, but frequently with no voltage change

_____ c. Area in which transformers are installed for safety protection, usually constructed with concrete and fire-retardant doors

_____ d. The temperature in the area where the transformer is to be located

Objective 2

List three basic types of transformers.

a. ______________________________

b. ______________________________

c. ______________________________

Written Test

Objective 3

Draw diagrams of the two most commonly used voltage systems.

a. Single phase transformer

b. Three phase transformer

Objective 4

Select true statements concerning *NEC* requirements for dry type transformers by placing an "X" in the blanks next to the true statements.

_____ a. Dry type transformers installed indoors rated at 112.5 KVA or less must have a fire resistant, heat insulating barrier between transformer and combustible materials.

_____ b. Dry type transformers require a 12" (305mm) separation or barrier if they are enclosed and are rated less than 112.5 KVA and will operate at 600V or less.

_____ c. Dry type transformers rated over 15,000 volts must be installed in a vault.

Objective 5

Complete statements concerning NEC requirements for oil-filled transformers by filling in the blanks with the correct answers.

a. Oil-filled transformers can be installed indoors and outdoors. When mounted indoors, oil-filled transformers must be mounted in a ____________________.

b. *NEC* Article 450.26 pertains to oil-insulated transformers which are installed ____________________.

c. *NEC* Article 450.27 pertains to oil-insulated transformers which are installed ____________________.

Objective 6

Select true statements concerning *NEC* requirements for askarel-filled transformers by placing an "X" in the blanks next to the true statements.

_____ a. Askarel-filled transformers are filled with a liquid called askarel which will not burn and is nonexplosive.

_____ b. Gases are produced as a result of arcing.

_____ c. A vent is not required if the transformer is under 115 KVA.

_____ d. NEC Article 450.25 pertains to askarel-insulated transformers installed indoors.

Objective 7

State the function of a buck and boost transformer.

____

____

____

____

Written Test

Objective 8

Match *NEC* articles with their correct transformer locations.

1. *NEC* Article 450.41
2. *NEC* Article 450.42
3. *NEC* Article 450.43
4. *NEC* Article 450.45
5. *NEC* Article 450.47
6. *NEC* Article 450.48

_____ a. Ventilation openings

_____ b. Transformer vaults

_____ c. Storage in vaults

_____ d. Doorways

_____ e. Walls, roofs, and floors

_____ f. Water pipes and accessories

Objective 9

Match *NEC* articles with the correct installation and termination of transformers.

1. *NEC* Article 450.2
2. *NEC* Article 450.10
3. *NEC* Article 240.4

_____ a. Mounting of transformers must comply with code on location, storage, and uses.

_____ b. Overcurrent protection may be installed on primary and secondary windings of transformers.

_____ c. Grounding of transformers.

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

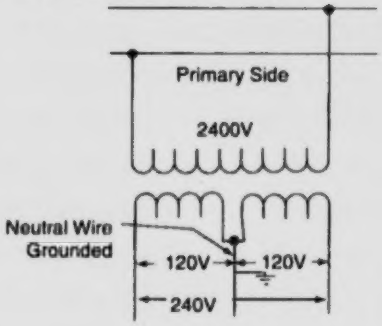
a. 2
b. 3
c. 4
d. 1

Objective 2

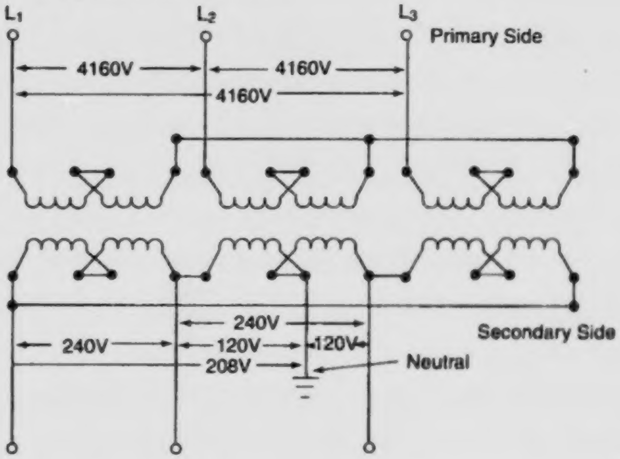
a. Dry type
b. Oil-filled
c. Askarel-filled

Objective 3

a. Single phase transformer


Primary Side
2400V
Neutral Wire Grounded
120V
120V
240V

b. Three phase transformer


L1
L2
L3
Primary Side
4160V
4160V
4160V
240V
240V
120V
120V
208V
Secondary Side
Neutral

Objective 4

a, b

Objective 5

a. Vault
b. Indoors
c. Outdoors

Answers to Written Test

Objective 6	a, b, d			
Objective 7	It is used to increase or decrease voltage.			
Objective 8	a.	4	d.	3
	b.	1	e.	2
	c.	6	f.	5
Objective 9	a.	1		
	b.	3		
	c.	2		

Teacher Supplement 1—Utility Company Methods for Delivering Electrical Power

- This supplement is intended to be used in conjunction with the Focus Assignment.

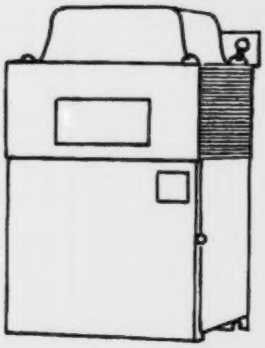
The power companies don't have any choice, and here's why. If a power company generates 6 megawatts (MW) and delivers it at 120V, it's easy to supply every user living around the generating plant. However, we can't all live right next to a generating plant. Power companies have to provide electric power to users who live far from the generating plant, using appropriate cable size and other transmission equipment.

Consider our example of 6,000,000 watts. Using the formula watts ÷ volts = amps or 6,000,000 watts ÷ 120 volts = 50,000 amps, we see that the conductor capable of passing 50,000 amps would be too large, and distribution would be impossible.

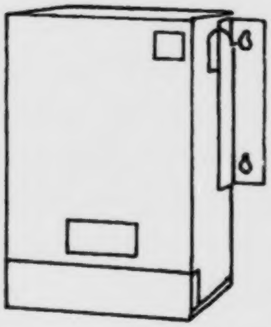
If we increased the voltage to 120,000 volts, then current for the same amount of power is: 6,000,000 ÷ 120,000 = 50 amps.

With increased voltage, current has been reduced allowing for the use of smaller size conductors and transmission equipment to convey the same amount of power. After reaching its destination, voltage is reduced back to 120V because of the risk of shock due to the presence of high voltage.

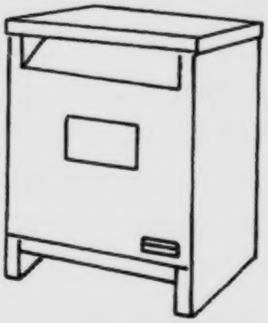
Basic Types of Transformers



Indoor

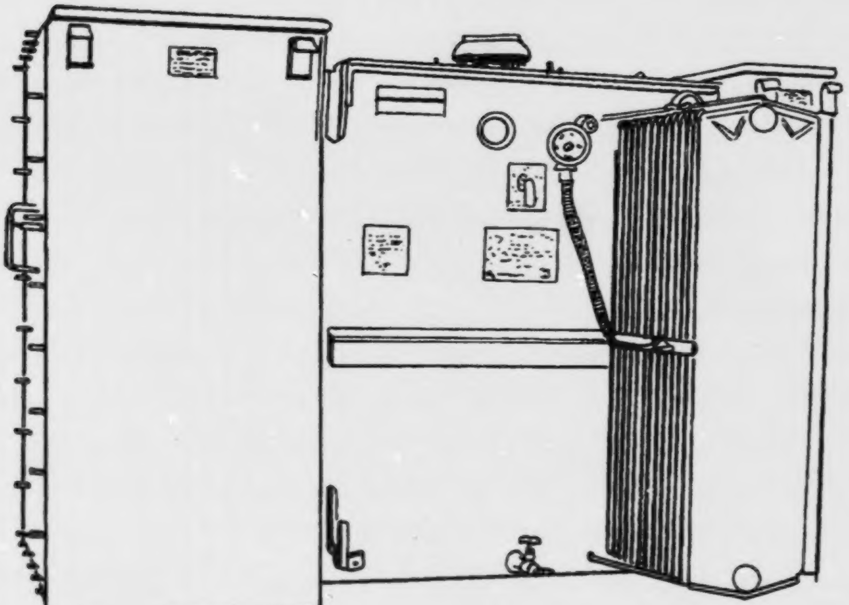


Outdoor



Floor Mount

Dry Type



Oil Filled

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* Job Sheets

1—Rough In a Wood Framed Wall 87
2—Install Outlet Boxes on Steel Rods 93
3—Install Outlet Boxes on Steel Studs Using Caddy Metal Stud Clips for Switch Boxes 97
4—Install Masonry Boxes in a Block Wall 101

* Assignment Sheet and Job Sheets are located in Student Workbook 1.

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make copies of any teacher supplements that will be provided for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

  TM 1 and 2—Bus Duct (Objective 3)
  TM 3—Cable Tray (Objective 3)
  TM 4—Cable Tray Fill (Objective 4)

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.

Suggested Activities

- Have students complete the focus assignment to introduce topics presented in unit of instruction.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheets. Review with students the criteria for evaluation of these activities.
- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Take students on a field trip to a commercial job in the area. Discuss with students the different areas being roughed in.
- Have a representative from a local supply house give a demonstration of trim out devices.
- Invite a local electrical contractor to class to talk about commercial jobs. Have students prepare written questions prior to the talk and ask them after the presentation.
- Set up several live troubleshooting projects in the lab, and demonstrate and discuss troubleshooting procedures. Distribute Teacher Supplement 1—Troubleshooting Procedures at this time.

  Note: The teaching of troubleshooting skills should be integrated throughout this publication.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the assignment sheets. Rate the student using the criteria listed on each assignment sheet. See Answers to Assignment Sheets for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.

Suggested Activities

- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

  Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

  Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

  Sample A

  4—**Skilled**—Can perform job with no additional training.
  3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
  2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
  1—**Unskilled**—Is familiar with process, but is unable to perform job.
  0—**No exposure**—No information or practice provided during training program.

  Sample B

  Yes—Can perform job with no additional training.
  No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Croft, Terrell and Wilford 1. Summers. *American Electrician's Handbook*, 13th Ed. New York: McGraw-Hill Book Company, 1999
- Earley, Mark W., John M. Caloggero and Richard H. Murray. *NEC Handbook 1993*. Quincy, MA: National Fire Protection Association, 1992.

- Kaltwasser, Stan and Gary Flowers. *Commercial and Industrial Wiring.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.
- *National Electrical Code, 2002.* Quincy, MA: National Fire Protection Association, 2001.
- *National Electrical Code 1999.* Quincy, MA: National Fire Protection Association, 1 998.
- *National Electrical Code 1993.* Quincy, MA: National Fire Protection Association, 1992.
- Teague, Cash and Garner Pewewardy. *Industrial Electricity: In-Plant Distribution.* Stillwater, OK: Oklahoma Curriculum and Instructional Materials Center, 1984.

Suggested Supplemental Resources

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- *2002 NEC Analysis of Changes.* Quincy, MA: National Fire Protection Association, 2001.

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  www.nfpa.org

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- Herman, Stephen L. *Electrician's Technical Reference: Industrial Electronics.* Delmar Publishers, Inc. 1999.
- Loyd, Richard. *Electrical Raceways and Other Wiring Methods,* 4th ed. Delmar Publishers, Inc. 2002.

- Miller, Chris. *Illustrated Guide to the National Electrical Code,* 2nd ed. Delmar Publishers, Inc. 2002.

  Conveniently groups Code requirements according to type of occupancy, and contains 600 illustrations

- Mullin, Ray and Robert Smith. *Electrical Wiring Commercial*, 11th ed. Delmar Publishers, Inc. 2002.
- Simpson, James G. *Common Sense Conduit Bending and Cable Tray Techniques*. Delmar Publishers, Inc. 1996.
- Smith, Robert and Stephen Herman. *Electrical Wiring Industrial*, 11th ed. Delmar Publishers, Inc. 2002.
- Surbrook, Truman and Jonathan Althouse. *Interpreting the National Electrical Code,* 6th ed. Delmar Publishers, Inc. 2002.

  Offer practical examples to illustrate how articles in the Code are applied

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Attn: Order Fulfillment
P.O. Box 6904
Florence, KY 41022
1-800-477-3692
www.delmar.com

Answers to Assignment Sheets

Assignment Sheet 1

Determine the Number of Conductors Allowed to be Added to an Existing Conduit

a. Area of conduit = **0.22 sq. in.**
Area of a #10 THW = 0.0333 sq. in.
Area of 6 #10 THW = (0.0333 X 6) sq. in.
= **0.1998 sq. in.**

Since 0.1998 sq. in. is less than 0.22 sq. in, the additional conductors are allowed.

Note: Annex C may also be used to solve this problem.

b. Area of conduit = **0.154 sq. in.**
Area of a #12 THHN = 0.0133 sq. in.
Area of 7-#12 THHN = (0.0133 X 7) sq. in.
= **0.0931 sq. in.**

Since 0.0931 sq. in. is less than 0.154 sq. in, the additional conductors are allowed.

Note: Annex C may also be used to solve this problem.

c. Area of conduit = **0.743 sq. in.**
Area of a 1/O THW = 0.2223 sq. in.
Area of 3-1/OTHW = (0.2223 X 3)sq.in.
= **0.6669 sq. in.**
Area of a #6 THHN = 0.0507 sq. in.
Area of 3-#6 THHN = (0.0507 X 3) sq. in.
= **0.1521 sq. in.**
Total area = 0.6669 + 0.1521
= **0.819 sq. in.**

Since 0.819 sq. in. is greater than 0.743 sq. in, a new conduit must be run.

d. Area of conduit = **0.829 sq. in.**
Area of a 1/0 THW = 0.2223 sq. in.
Area of 3-1/OTHW = (0.2223 X 3)sq.in.
= **0.6669 sq. in.**
Area of a #6 THHN = 0.0507 sq. in.
Area of 3-#6 THHN = (0.0507 X 3) sq. in.
= **0.1521 sq. in.**
Total area = 0.6669 + 0.1521
= **0.819 sq. in.**

Since 0.819 sq. in. is less than 0.829 sq. in., the additional conductors are allowed.

Written Test

Name ______________________________

Date ______________________ Score __________

Objective 1

Match the terms related to rough-in with their definitions. Write the correct numbers in the blanks. Definitions continue on the next page.

1. Ampacity
2. Cable bender
3. Copper-clad aluminum
4. Color coding
5. Covered
6. Cross-sectional area
7. Drop chain
8. Fish
9. Fish tape
10. Insulated
11. Pipe chase
12. Power fish-tape system
13. Pull rope
14. Raceway
15. Trim out
16. Troubleshooting
17. Voltage rating
18. Wire dispenser
19. Wire-pulling compound
20. Winch

_____ a. Assigning colors to conductors based on their uses

_____ b. The systematic diagnosis of a malfunction

_____ c. An enclosed channel designed expressly for holding wires, cables, or busbars, with additional functions as permitted in the *National Electrical Code*

_____ d. The current in amperes that a conductor can carry continuously under the conditions of use without exceeding its temperature rating

_____ e. Strong rope of nylon or other substance used to pull heavy conductors into raceways

_____ f. Maximum and minimum voltage at which a device is designed to operate

_____ g. Compound of soap and other substances used to lubricate conductors being pulled or pushed into a raceway

_____ h. Establishing a connection between two points so a cable or length of flexible conduit can be installed

_____ i. Mechanical or hydraulic device used to bend heavy conductors in panels and junction boxes

_____ j. Conductor encased within material of composition and thickness not recognized by the *National Electrical Code* as electrical insulation

_____ k. Final stage in a wiring project; involves devices and plates, connecting and securing equipment, hanging fixtures, and testing the system

_____ l. Movable rack used to hold one or more reels of wire so that wire can be easily pulled off reel and fed into raceway

_____ m. Aluminum conductor with an outer coating of copper metallurgically bonded to the aluminum core

_____ n. Area in square inches allowed in a raceway

_____ o. Usually a vertical space between two floors, dedicated for the running of pipes and conduits between floors

_____ p. Short length of small chain used to pull conductors or flexible conduit through an enclosed space or wall cavity

_____ q. Long tape of steel, nylon, or other material used to push or pull conductors into a raceway

_____ r. Conductor encased within material of composition and thickness recognized by the *National Electrical Code* as electrical insulation

_____ s. Manual or motor-powered mechanical device used to pull conductors into a raceway

_____ t. Vacuum or air pressure system for installing a pull cord in a raceway in order to pull in the heavy pull rope for heavy and long pulls

Objective 2

Select true statements concerning branch circuit and feeder installation by placing an "X" in the blank preceding each true statement.

_____ a. When using multi-phase circuitry, balancing must take place to regulate the even flow of current on each of the phases.

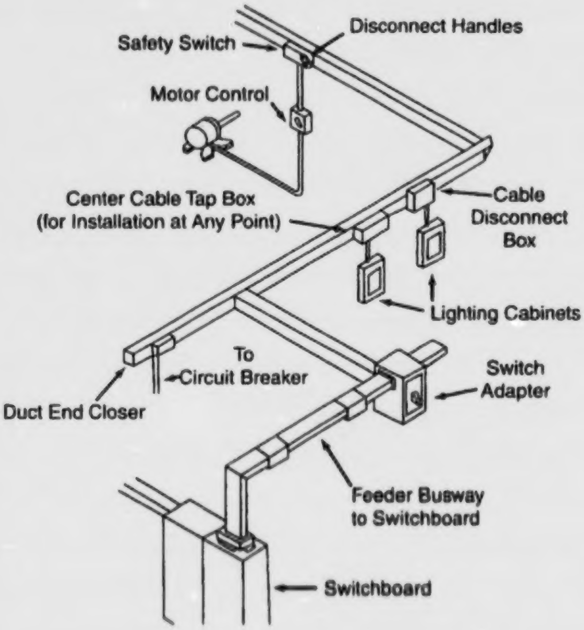
_____ b. Color coding for a high leg delta 4-wire system must be marked with yellow color and must be located on center lug.

_____ c. When identifying neutrals, the *NEC* states that conductors not white must be marked with continuous white or gray tape, or white paint.

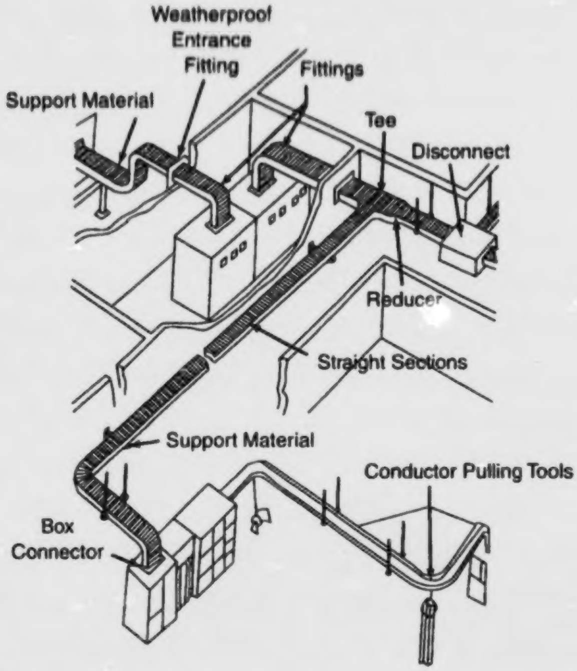
_____ d. Temporary lighting shall be protected from accidental contact or breakage by a suitable fixture or lampholder with a guard.

Objective 3

Identify devices used in special circuit installations.


Safety Switch
Disconnect Handles
Motor Control
Center Cable Tap Box (for Installation at Any Point)
Cable Disconnect Box
Lighting Cabinets
To Circuit Breaker
Duct End Closer
Switch Adapter
Feeder Busway to Switchboard
Switchboard

a. ______________________


Weatherproof Entrance Fitting
Fittings
Support Material
Tee
Disconnect
Reducer
Straight Sections
Support Material
Conductor Pulling Tools
Box Connector

b. ______________________

Written Test

Objective 4

Select true statements concerning requirements for cable tray systems by placing an "X" in the blank preceding the true statement.

_____ a. Where conductors 1/0 through 4/0 are run in ladder type trays, the maximum rung spacing must not exceed 12 inches.

_____ b. The NEC requires that all metallic cable trays be grounded in accordance with conductor enclosures in Article 250.

_____ c. Solid fixed barrier of material compatible with the cable tray must separate multiconductor cables of over 600V and those of 600V or less where they are installed in the same cable tray.

_____ d. In portions of dairies, laundries, canneries, and other indoor wet locations, the entire wiring system and fittings, where installed exposed, shall be mounted so that there is at least a 1/2" air-space between it and the wall or supporting surface.

_____ e. Single conductors must be 1/0 or larger, and cables must be identified as being sunlight-resistant if they are exposed to direct sunlight.

Objective 5

Arrange in order the steps for determining the number of conductors allowed in a conduit based on cross-sectional area by numbering from 1 to 5.

_____ a. Compute total area occupied by existing conductors based on Table 5, Chapter 9 of the NEC.

_____ b. Determine size of existing conduit.

_____ c. Determine number of conductors that may be added.

_____ d. Find area of conduit or tubing using Table 4, Chapter 9 of the NEC.

_____ e. Determine number and size of existing conductors.

Objective 6

List five types of acceptable wiring methods for commercial and industrial projects.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

Objective 7

Complete statements concerning conditions for using the optional calculations for additional loads to existing installations by filling in the blanks with the correct answers.

a. The maximum demand data is available in KVA for a minimum of a ____________________ period.

b. The existing demand at 125 percent plus the new load does not exceed the ampacity of the feeders or ____________________ of the service.

c. The feeder or service has ____________________ in accordance with sections 230.90 and 240.3 of the *NEC*.

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a. 4
b. 16
c. 14
d. 1
e. 13
f 17
g. 19
h 8
i. 2
j 5
k. 15
1. 18
m 3
n. 6
o. 11
p 7
q. 9
r. 10
s. 20
t 12

Objective 2

a,c,d

Objective 3

a. Bus duct
b. Cable tray

Objective 4

b, c, e

Objective 5

a. 4
b 1
c. 5
d 3
e. 2

Objective 6

Answer should include any five of the following

a. Mineral Insulated Metal Sheathed Cable
b. Electrical Nonmetallic Tubing
c. Armored Cable (AC)
d. Metallic Clad (MC)
e. Non-Metallic Sheathed Cable (Type NM, NMC, and NMS)
f. Non-Metallic Underground Conduit with conductors
9. Intermediate Metal Conduit
h. Rigid Metal Conduit
i. Rigid Nonmetal Conduit
j. Electrical Metallic Tubing
k. Flexible Metal Conduit

Objective 7

a. One year
b. Rating
c. Overcurrent protection

Teacher Supplement 1—Troubleshooting Porcedures

1. Determine the symptoms of the system malfunction. Consult the owner about the operation of the system before, during, and after the problem occurred.

   Note: A great deal of information can be gained from this questioning—Did it flicker, hum, or explode? Was anything unusual going on at the time of the problem (lightning, unusual load, too many appliances plugged in)? Has it happened before?

2. Inspect the system.

   Note: The panel is the place to start, because the overcurrent protection device will identify the problem circuit. Most national, state, and local codes require that panels be identified.

   a. Trace the system from the panel by:

      - Color of conductor
      - Number of conductor
      - Using an ohmmeter

      Caution: Always disconnect the supply power from the circuit to be tested before using an ohmmeter. Line voltages will damage the meter.

   b. Check the conductor's condition.

      - Is the conductor discolored from overheating?
      - Is the conductor insulation damaged or nicked?
      - Is there a loose conductor connection at devices or splice points?

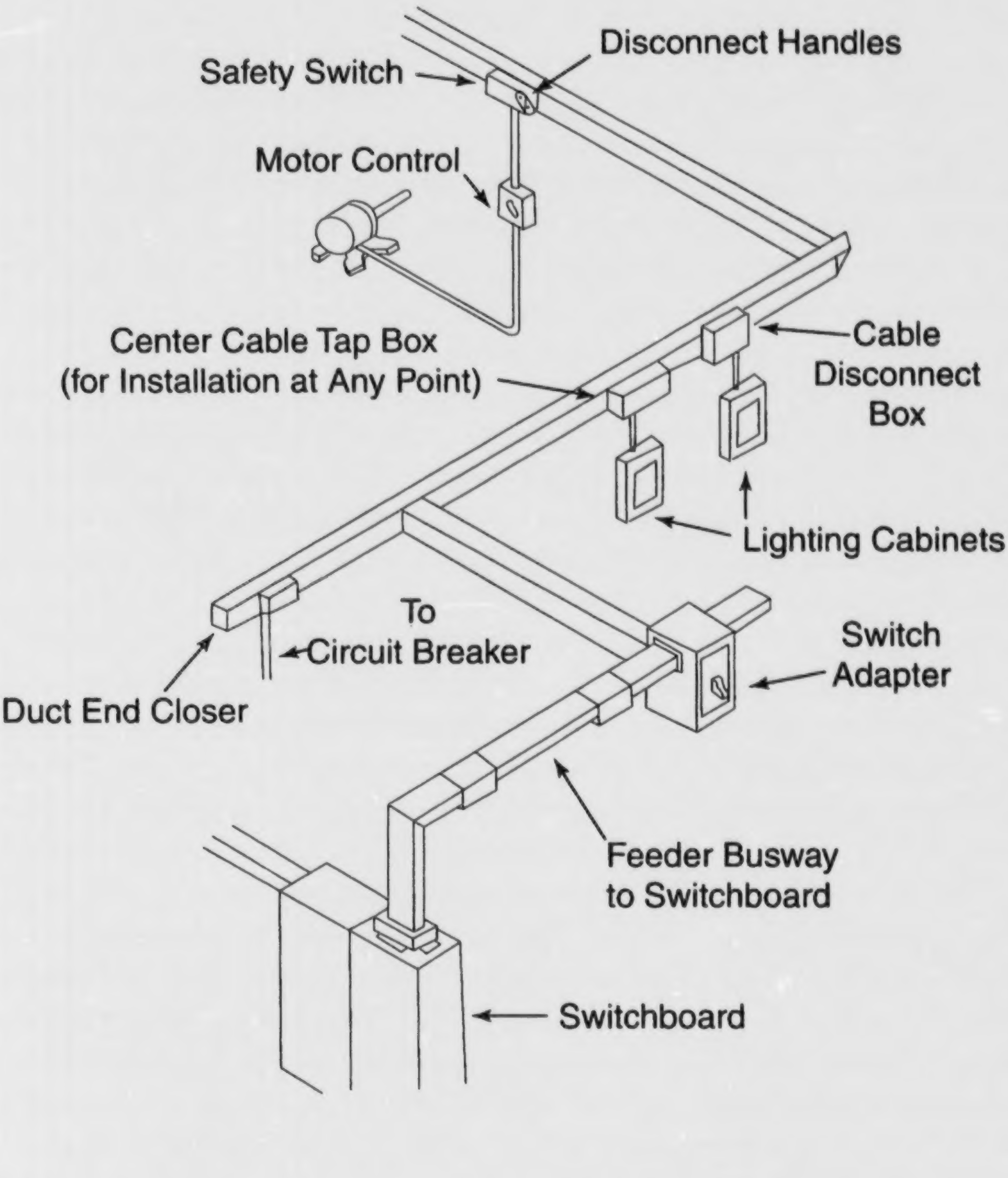
   c. Check devices or fixtures

      - Is the device worn or overheated?
      - Is the fixture worn or overheated?
      - Is there reversed outlet polarity which may cause neutral overload?

        Note: Fixtures with bulbs larger than their rating may have internal damage.

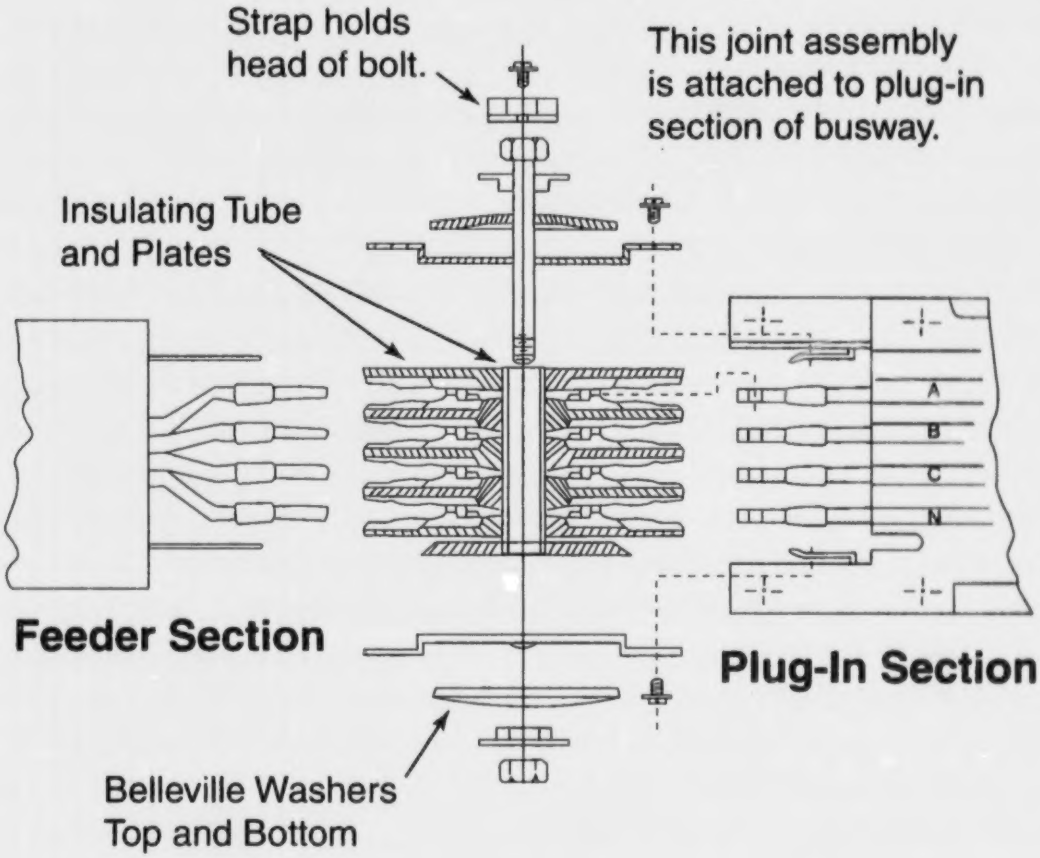
3. Locate the problem causing area.
   - Is it a bad device or fixture?
   - Is it a broken conductor?
   - Is it a circuit overload?
4. Repair or replace the cause of the problem.
   - Install a new device or fixture.
   - Rewire the circuit.
   - Install an extra circuit to compensate for overload.

Bus Duct


Disconnect Handles
Safety Switch
Motor Control
Center Cable Tap Box
(for Installation at Any Point)
Cable
Disconnect
Box
Lighting Cabinets
To
Circuit Breaker
Switch
Adapter
Duct End Closer
Feeder Busway
to Switchboard
Switchboard

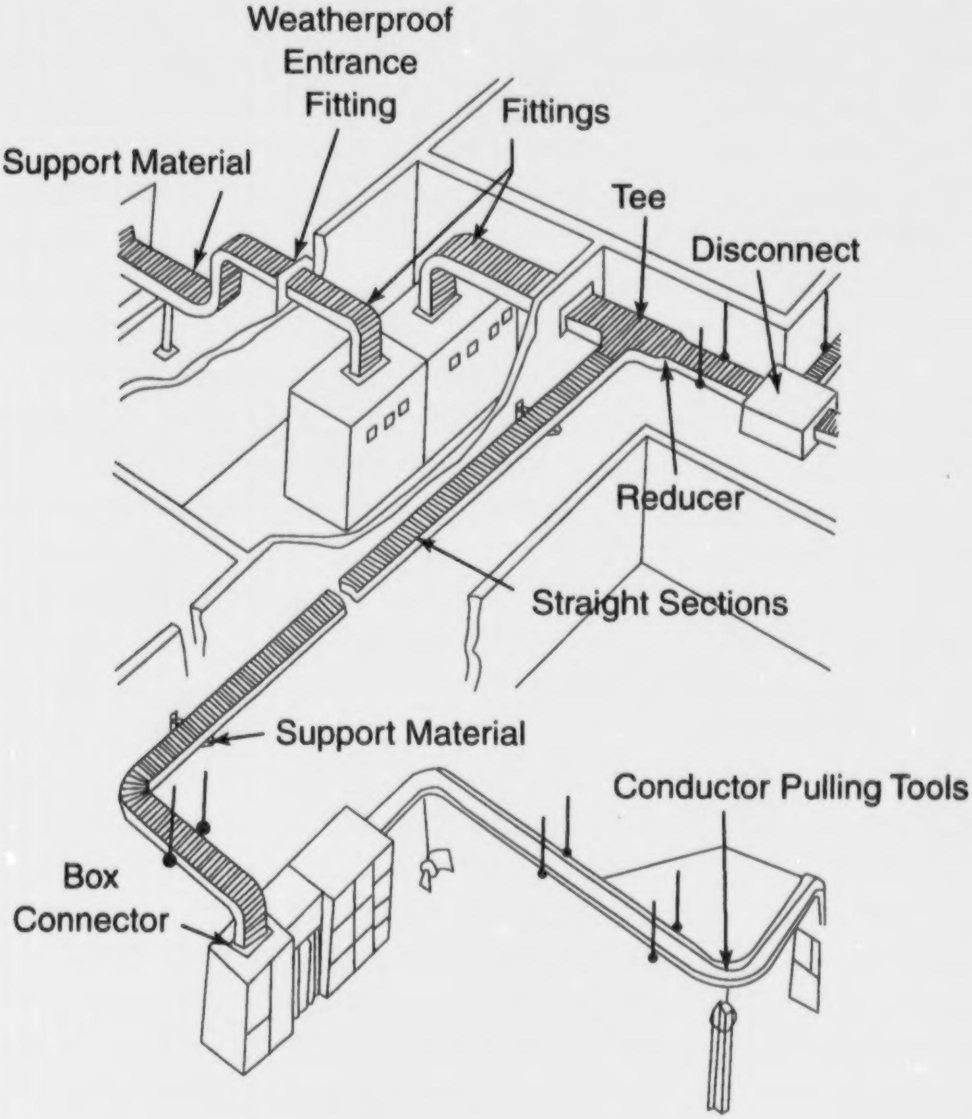
TM 1

Bus Duct (continued)


Strap holds head of bolt.
This joint assembly is attached to plug-in section of busway.
Insulating Tube and Plates
A
B
C
N
Feeder Section
Plug-In Section
Belleville Washers Top and Bottom

One Bolt Joint Assembly

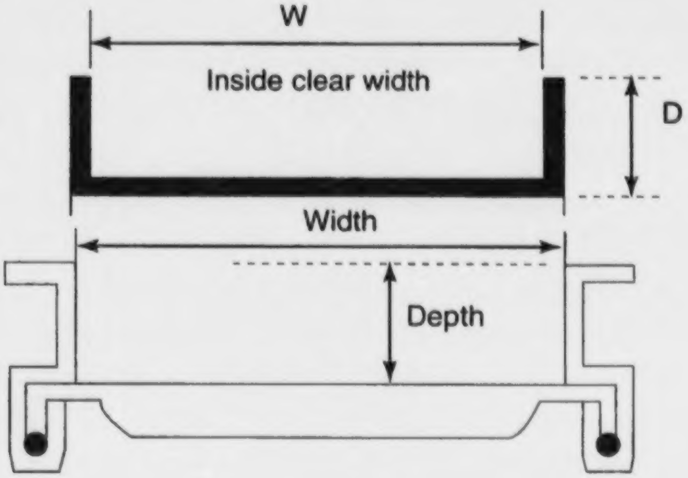
Cable Tray


Weatherproof Entrance Fitting
Fittings
Support Material
Tee
Disconnect
Reducer
Straight Sections
Support Material
Conductor Pulling Tools
Box Connector

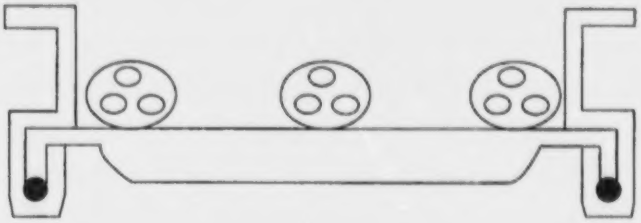
TM 3

Cable Tray Fill

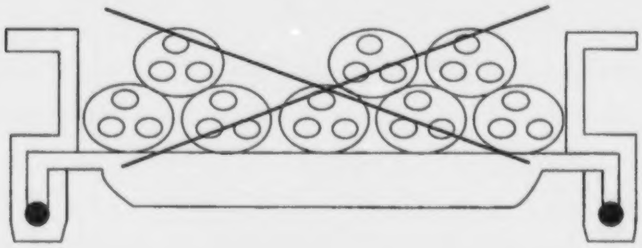
NEC Art 392.3(A) through (E), and 392.10, 392.11.


W
Inside clear width
D
Width
Depth

This cable arrangement is better than the one below.



Cables packed closely together can affect the efficiency of each other



Unit Contents

Teacher Components

Teacher Page

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Teacher Supplement

1—Troubleshooting Procedures—Fluorescent Lighting 6–17

Student Components

Student Page

Learning Activities Sheet 6–3

Objective Sheet 6–5

Information Sheet 6–7

* Assignment Sheet

1—Locate Articles in the *NEC* Concerning Lighting Requirements 105

* Job Sheets

1—Change a Two-Lamp Ballast in a Fluorescent Fixture 107
2—Change Sockets in a Fluorescent Fixture 109
3—Change an HID Ballast 111
4—Change a Quartz Lamp 113

* Assignment Sheet and Job Sheets are located in Student Workbook 1.

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make copies of any teacher supplements that will be provided for each student.

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Have students complete the focus assignment to introduce topics presented in unit of instruction.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.

Suggested Activities

- Discuss the assignment sheets. Review with students the criteria for evaluation of these activities.
- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Invite a representative from a ballast company to show and discuss the various types of ballasts and their functions.
- Show a film on advance ballast lighting.
- Set up a display of the various types of lighting and point out special features.
- Take students on a field trip to view different types of lighting used in commercial and industrial buildings. Have students take notes and discuss their observations in class.
- Provide students with a copy of Teacher Supplement 1—Troubleshooting Procedures. Discuss and demonstrate procedures.
- Provide students with troubleshooting problems to practice the procedures listed in Teacher Supplement 1.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the assignment sheets. Rate the student using the criteria listed on each assignment sheet. See Answers to Assignment Sheets for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.
- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

Sample A

4—**Skilled**—Can perform job with no additional training.
3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
1—**Unskilled**—Is familiar with process, but is unable to perform job.
0—**No exposure**—No information or practice provided during training program.

Sample B

Yes—Can perform job with no additional training.
No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Kaltwasser, Stan and Gary Flowers. *Commercial and Industrial Wiring*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.
- Mullin, Ray C. and Robert L. Smith. *Electrical Wiring: Commercial*, 8th Ed. Albany, NY: Delmar Publishers, inc., 1993.
- *National Electrical Code, 2002*. Quincy, MA: National Fire Protection Association, 2001.
- *National Electrical Code* 1999. Quincy, MA: *National Fire Protection Association*, 1998.
- *National Electrical Code* 1993. Quincy, MA: *National Fire Protection Association*, 1992.
- *Pocket Guide to Fluorescent Lamp Ballasts*. Carrolton, TX: Advance Transformer Company, 1986.
- *Pocket Guide to HID Lamp Ballasts*. Carrolton, TX: Advance Transformer Company, 1986.

Suggested Activities

Suggested Supplemental Resources

Print Media

- *2002 NEC Analysis of Changes.* Quincy, MA: National Fire Protection Association, 2001.

  Provides a detailed view of the most important changes in the 2002 NEC

- *NEC 2002 Handbook.* Quincy, MA: National Fire Protection Association, 2001.

  Contains complete Code text plus commentary, photos, and full-color graphics

  The publication(s) listed above can be ordered from:

  National Fire Protection Association
  1 Batterymarch Park
  Quincy, MA 02269-9101
  1-800-344-3555
  www.nfpa.org

- Early, Mark W., et al. *Illustrated Changes in the National Electrical Code.* Delmar Publishers, Inc. 2002.

  Provides a detailed view of the most important changes in the 2002 NEC

- Herman, Stephen L. *Electrician's Technical Reference: Industrial Electronics.* Delmar Publishers, Inc. 1999.

- Miller, Chris. *Illustrated Guide to the National Electrical Code,* 2nd ed. Delmar Publishers, Inc. 2002.

  Conveniently groups Code requirements according to type of occupancy, and contains 600 illustrations

- Mullin, Ray and Robert Smith. *Electrical Wiring Commercial,* 11th ed. Delmar Publishers, Inc. 2002.

- O'Riley, Ronald. *Electrical Grounding,* 6th ed. Delmar Publishers, Inc. 2002.

- Smith, Robert and Stephen Herman. *Electrical Wiring Industrial,* 11th ed. Delmar Publishers, Inc. 2002.

- Surbrook, Truman and Jonathan Althouse. *Interpreting the National Electrical Code,* 6th ed. Delmar Publishers, Inc. 2002.

  Offer practical examples to illustrate how articles in the Code are applied

- Titus, Patricia A., et al. *Illustrated Dictionary for Electrical Workers,* 2nd ed. Delmar Publishers, Inc. 2002.

The publication(s) listed above can be ordered from:

Thompson Learning
Attn: Order Fulfillment
P.O. Box 6904
Florence, KY 41022
1-800-477-3692
www.delmar.com

Electronic Media

- Advance Transformer Company—www.advancetransformer.com Contains lots of information on ballasts.
- www.lightresource.com—Good source for links to the lighting industry.
- www.light-link.com—Good search engine for finding manufacturers, products, and resources.
- www.qualitylight.com—Excellent resource center and reference library.
- Electrical Wiring Residential Video Series, 2001 (set of eight)

Video 1: Introduction to Electrical Installations
Video 2: Planning for Circuit Installation
Video 3: Special Circuits
Video 4: Lighting By the Room
Video 5: GFCI's
Video 6: Special Purpose Circuits
Video 7: Miscellaneous and Custom Installations
Video 8: Service Entrances

Available on video or CD-ROM, this set can be purchaesd online at 222.delmar.com or by calling 800-477-3692

Answers to Assignment Sheets

Assignment Sheet 1

Locate Articles in the *NEC* Concerning Lighting Requirements

a. 410.78
b. 410.67(C)
c. 700.20
d. 410.4
e. 410.83
f. 410.100–105

Written Test

Name ____

Date ______________________________ Score __________

Objective 1

Match the terms related to lighting with their definitions. Write the correct numbers in the blanks. Definitions continue on the next page.

1. B
2. Ballast
3. Cathode
4. Coefficient
5. CW
6. D
7. Fluorescent lighting
8. FC
9. G
10. HID
11. Incandescent lighting
12. Lumen
13. PK
14. Photocell
15. Photometer
16. Phosphor
17. W
18. WW

_____ a. Green lamp

_____ b. Light activated switch

_____ c. White lamp

_____ d. Footcandles

_____ e. Transformer used in lighting circuits

_____ f. Electric discharge lighting

_____ g. Instrument used to determine lumens

_____ h. Warm white lamp

_____ i. Coating inside a fluorescent bulb that determines the color of light

_____ j. A unit of light emitted from a point light source of one candle through a unit solid angle

_____ k. High intensity discharge

_____ l. Daylight lamp

_____ m. Consists of a filament which is a highly refractory conductor mounted in a transparent or translucent glass bulb

_____ n. Cool white lamp

_____ o. Blue lamp

_____ p. Coiled coil or triple coil tungsten wire at each end of lamp which is coated with material that emits electrons

_____ q. Pink lamp

_____ r. The square root of the ratio of the power reflected from a surface to the power incident of the same surface

Written Test

Objective 2

List three basic types of lighting.

a. ____________________

b. ____________________

c. ____________________

Objective 3

Select true statements concerning characteristics of incandescent lighting by placing an "X" in the blanks next to the true statements.

_____ a. Incandescent lamps have the highest efficiency rating of any lamps and are the most popular type because of the low cost.

_____ b. Incandescent lamps come in many different sizes and shapes.

_____ c. Incandescent lamps have different bases.

Objective 4

Complete statements concerning characteristics of fluorescent lighting by filling in the blanks with the correct answers.

a. Classification of fluorescent lamps is determined by the type, length or wattages, shape and ____________________.

b. The color of a fluorescent lamp depends on the ____________________ used inside the lamp.

c. There are four types of contacts found on tube bases of fluorescent lamps: single pin, bi-pin, four pin and ______________ ______________ ______________.

d. There are three types of fluorescent tubes: ____________________, rapid-start, and instant-start.

e. Instant-start systems produce light instantly by providing ______________ ______________ ______________ to the lamp electrodes, at about three times the normal lamp operating voltage.

Objective 5

Complete statements concerning characteristics of high intensity discharge lamps by filling in the blanks with the correct answers.

a. There are four basic types of HID lamps used in the lighting industry: ____________________, metal halide, high pressure sodium, and low pressure sodium.

b. ______________ and ______________ lamps have an additional electrode to assist lamp starting while others have no starting electrodes.

c. When power is lost, HID lighting goes through a ______________ period before coming back on.

d. HID lighting provides greater ______________ for the cost of operation.

Objective 6

Complete statements concerning characteristics of ballast by filling in the blanks with the correct answers.

a. While the lamp is in operation, the ballast regulates the ____________________ ____________________ flowing through the lamp to stabilize light output.

b. To start the lamp, a ballast provides the proper voltage to establish an ____________________ between the two electrodes.

c. A hybrid ballast incorporates electronic circuitry to disconnect the ______________ ______________ ______________ after the lamp ignites.

d. An electronic ballast operates the lamp at a frequency of ____________________ Hz or greater.

Objective 7

List three methods of calculating light.

(Hint: Two methods use formulas to calculate light.)

a. ____

b. ____

c. ____

Objective 8

Complete statements concerning calculating branch circuits and voltage by circling the numbers which best complete each statement.

a. When calculating branch circuits for lighting loads of not less than that specified in *NEC* Table 220.3(A), the minimum lighting load for each square foot is (**0.039, 0.093**) square meters of floor area.

b. Ballasts should operate within (**$\pm 7^{1}/2\%$, $\pm 5^{1}/2\%$**) of rated voltage.

Objective 9

Select true statements concerning switching systems by placing an "X" in the blanks next to the true statements.

_____ a. Switches, photocells, and magnetic lighting contactors may be used to control lighting circuits.

_____ b. A photocell is a switch activated by light or motion.

_____ c. Lighting contactors are used when photocells and switches control the lighting amperage.

_____ d. Switches and dimmers may be used on fluorescent and HID lighting.

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a. 9
b. 14
c. 17
d. 8
e. 2
f. 7
g. 15
h. 18
i. 16
j. 12
k. 10
l. 6
m. 11
n. 5
o. 1
p. 3
q. 13
r. 4

Objective 2

a. Incandescent
b. Fluorescent
c. High intensity discharge (HID)

Objective 3

b, c

Objective 4

a. Color
b. Phosphor
c. Recessed double contact
d. Preheat
e. Open circuit voltage

Objective 5

a. Mercury
b. Mercury, metal halide
c. Cooling
d. Lumens-per-watt

Objective 6

a. Electric current
b. Arc
c. Cathode heater windings
d. 20,000

Objective 7

a. $\text{Footcandles} = \dfrac{\text{Lumens on a Surface}}{\text{Area of Surface in Square}}$

b. F=12.57 x I LM
c. Photometer

Objective 8

a. 0.093
b. $\pm 7^{1}/_{2}\%$

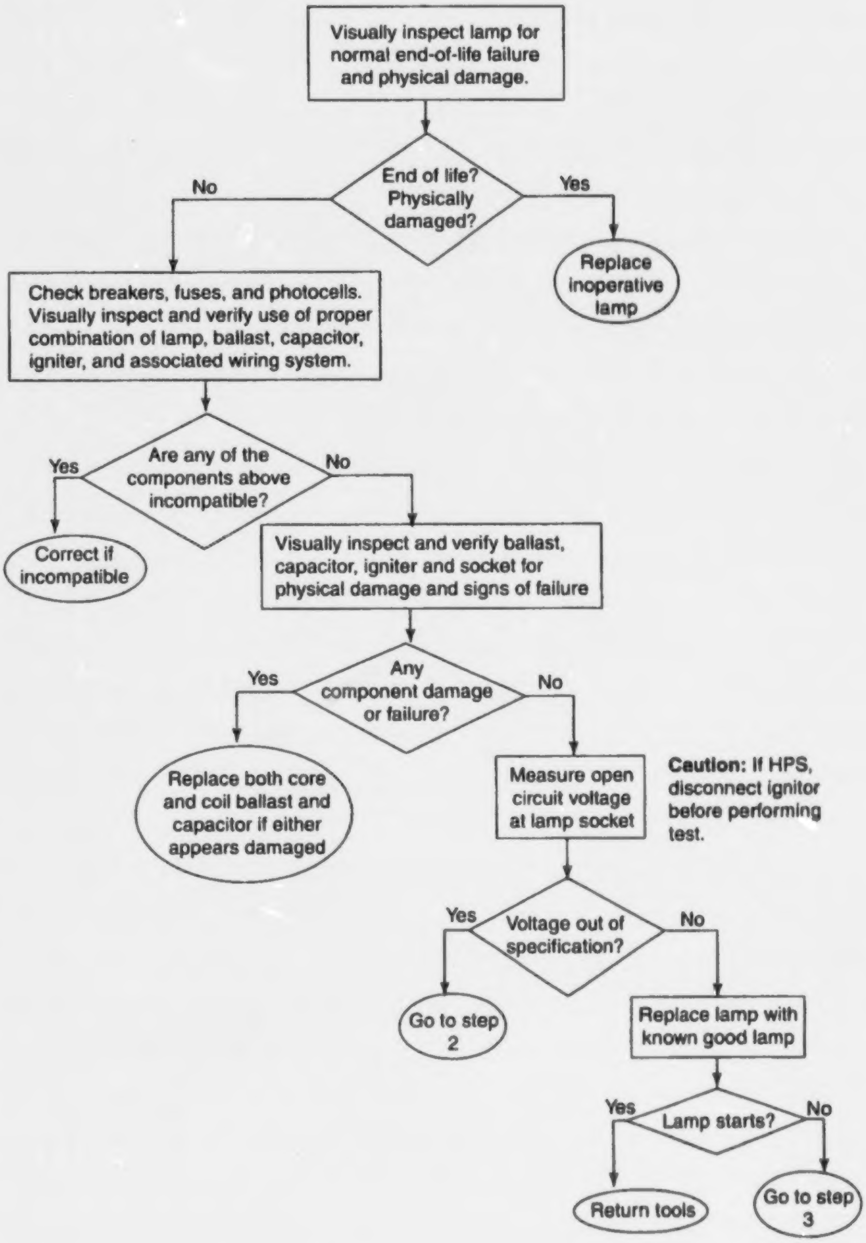
Objective 9

a, d

Teacher Supplement 1—Troubleshooting Procedures—Fluorescent Lighting

Step 1

Lamp will not start

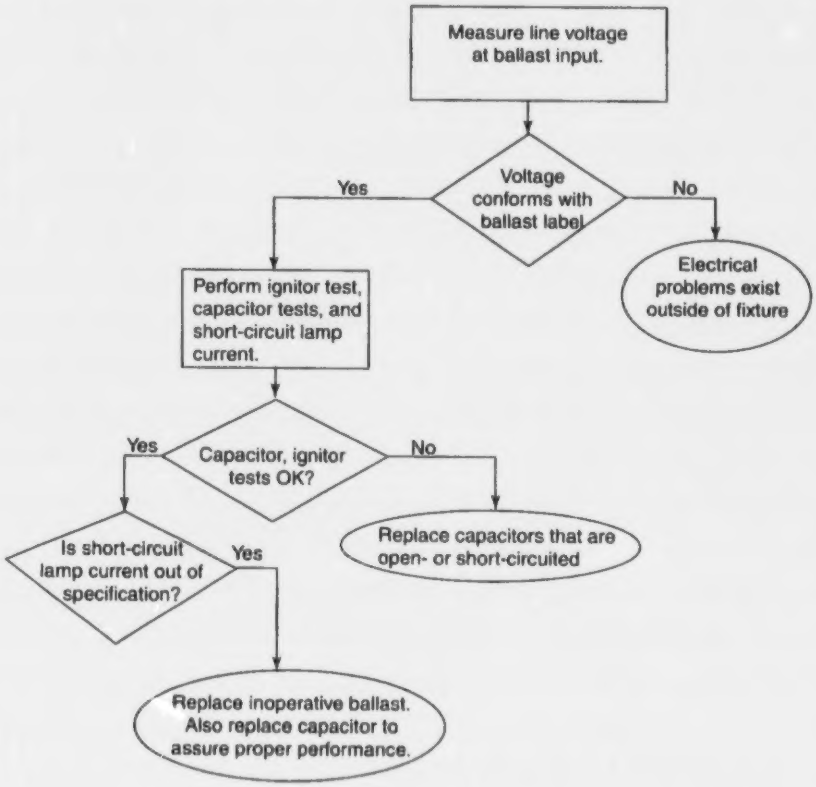

Visually inspect lamp for normal end-of-life failure and physical damage.
End of life? Physically damaged?
No
Yes
Replace inoperative lamp
Check breakers, fuses, and photocells. Visually inspect and verify use of proper combination of lamp, ballast, capacitor, igniter, and associated wiring system.
Are any of the components above incompatible?
Yes
No
Correct if incompatible
Visually inspect and verify ballast, capacitor, igniter and socket for physical damage and signs of failure
Any component damage or failure?
Yes
No
Replace both core and coil ballast and capacitor if either appears damaged
Measure open circuit voltage at lamp socket
Voltage out of specification?
Yes
No
Go to step 2
Replace lamp with known good lamp
Lamp starts?
Yes
No
Return tools
Go to step 3

Caution: If HPS, disconnect ignitor before performing test.

Teacher Supplement 1

Step 2

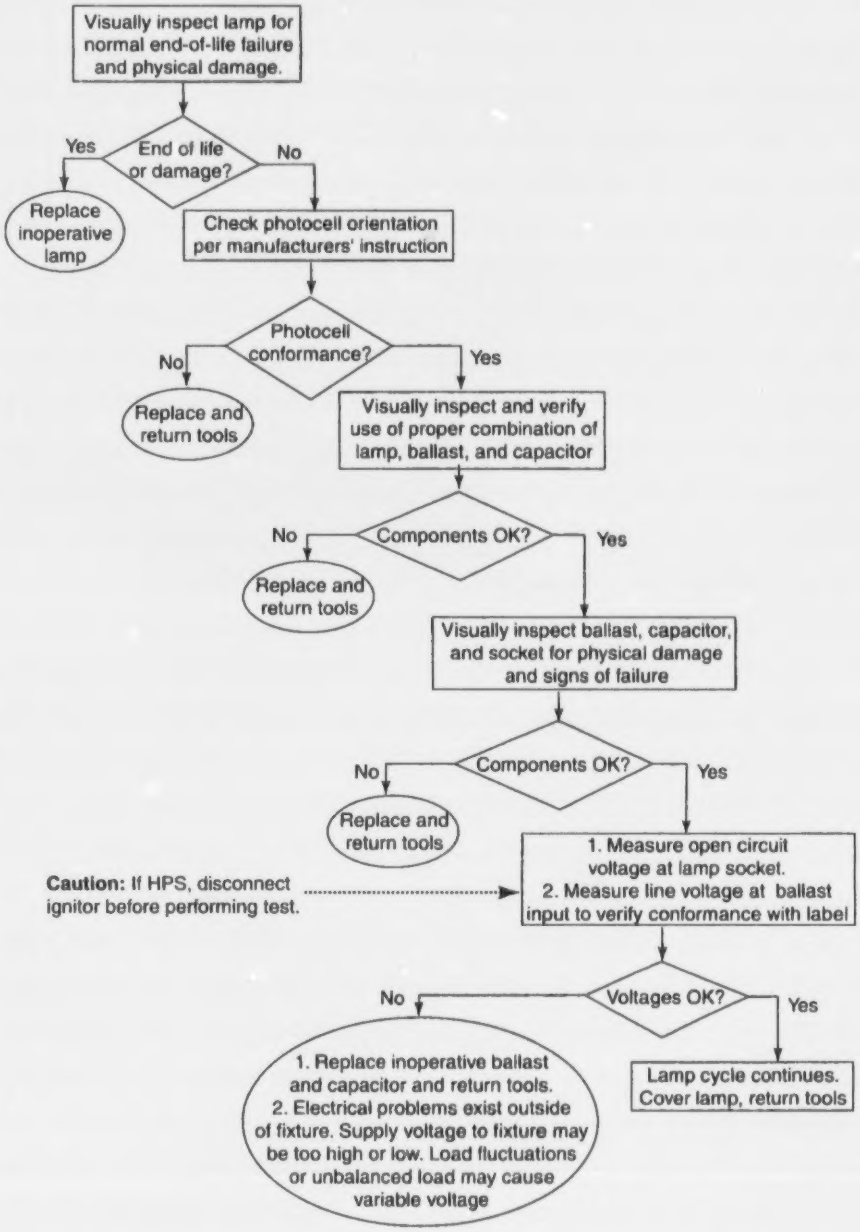
Open circuit voltage out of specification


Measure line voltage at ballast input.
Voltage conforms with ballast label
Yes
No
Electrical problems exist outside of fixture
Perform ignitor test, capacitor tests, and short-circuit lamp current.
Capacitor, ignitor tests OK?
Yes
No
Replace capacitors that are open- or short-circuited
Is short-circuit lamp current out of specification?
Yes
Replace inoperative ballast. Also replace capacitor to assure proper performance.

Step 3

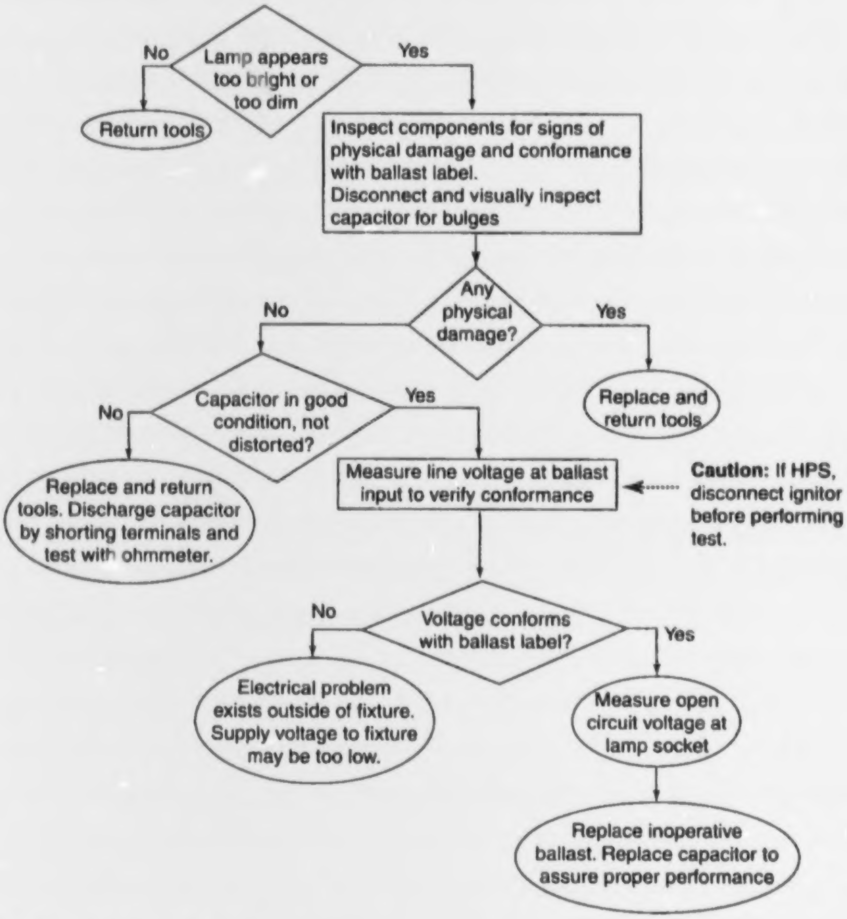
Teacher Supplement 1

Lamp cycles


Visually inspect lamp for normal end-of-life failure and physical damage.
End of life or damage?
Yes
No
Replace inoperative lamp
Check photocell orientation per manufacturers' instruction
Photocell conformance?
No
Yes
Replace and return tools
Visually inspect and verify use of proper combination of lamp, ballast, and capacitor
Components OK?
No
Yes
Replace and return tools
Visually inspect ballast, capacitor, and socket for physical damage and signs of failure
Components OK?
No
Yes
Replace and return tools
1. Measure open circuit voltage at lamp socket.
2. Measure line voltage at ballast input to verify conformance with label
Voltages OK?
No
Yes
1. Replace inoperative ballast and capacitor and return tools.
2. Electrical problems exist outside of fixture. Supply voltage to fixture may be too high or low. Load fluctuations or unbalanced load may cause variable voltage
Lamp cycle continues. Cover lamp, return tools

Caution: If HPS, disconnect ignitor before performing test.

Lamp too bright or dim


Lamp appears too bright or too dim
No
Yes
Return tools
Inspect components for signs of physical damage and conformance with ballast label.
Disconnect and visually inspect capacitor for bulges
Any physical damage?
No
Yes
Replace and return tools
Capacitor in good condition, not distorted?
No
Yes
Replace and return tools. Discharge capacitor by shorting terminals and test with ohmmeter.
Measure line voltage at ballast input to verify conformance
Caution: If HPS, disconnect ignitor before performing test.
Voltage conforms with ballast label?
No
Yes
Electrical problem exists outside of fixture. Supply voltage to fixture may be too low.
Measure open circuit voltage at lamp socket
Replace inoperative ballast. Replace capacitor to assure proper performance

Courtesy of Advance Transformer Company

Unit Contents

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Student Components

Student Page

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* Assignment Sheets

1—Interpret Nameplate Information 115
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Unit Contents

* Job Sheets

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3—Test Capacitors with an Ohmmeter 135
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5—Perform Maintenance on a Magnetic Contactor 139

* Assignment Sheets and Job Sheets are located in Student Workbook 1.

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make copies of any teacher supplements that will be provided for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

TM 1—Magnetic Poles in an Electric Motor (Objective 3)
TM 2—Polyphase Magnetism (Objective 3)
TM 3—Squirrel Cage Rotor (Objective 7)
TM 4—Delta-Wound Motor (Objective 7)
TM 5—Wye-Wound motor (single speed) (Objective 7)
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TM 8—Dual Voltage Three-Phase Motor Showing Possible Twelve Leads (Objective 11)
TM 9—Types of Magnetic Contactor Assemblies (Objective 15)

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Suggested Activities

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Have students complete the focus assignment to introduce topics presented in unit of instruction.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheets. Review with students the criteria for evaluation of these activities.
- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Visit a motor winding shop. Discuss observations with the class.
- Visit a local industry and view types of motors and controllers used. Encourage students to question why certain types were chosen for a particular job.
- Invite a local maintenance or industrial electrician to speak on the importance of controllers and motors. Encourage note taking and questions.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the assignment sheets. Rate the student using the criteria listed on each assignment sheet. See Answers to Assignment Sheets for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.

Suggested Activities

- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

  Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

  Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

  Sample A

  4—**Skilled**—Can perform job with no additional training.
  3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
  2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
  1—**Unskilled**—Is familiar with process, but is unable to perform job.
  0—**No exposure**—No information or practice provided during training program.

  Sample B

  Yes—Can perform job with no additional training.
  No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Adams, James and Gordon Rockmaker. *Industrial Electricity: Principles and Practices*, 3rd Ed. New York: McGraw-Hill Book Company, 1985.
- Kaltwasser, Stan and Gary Flowers. *Commercial and Industrial Wiring.* Stillwater, OK: Mid-America Vocational and Curriculum Consortium, 1988.

- *National Electrical Code, 2002*. Quincy, MA: National Fire Protection Association, 2001.
- *National Electrical Code 1993*. Quincy, MA: National Fire Protection Association, 1992.
- Teague, Cash and Garner Pewewardy. *Industrial Electricity: In-Plant Distribution.* Stillwater, OK: Oklahoma Curriculum and Instructional Materials Center, 1984.

Suggested Supplemental Resources

Print Media

- *2002 NEC Analysis of Changes*. Quincy, MA: National Fire Protection Association, 2001.

  Provides a detailed view of the most important changes in the 2002 NEC

- *NEC 2002 Handbook*. Quincy, MA: National Fire Protection Association, 2001.

  Contains complete Code text plus commentary, photos, and full-color graphics

  The publication(s) listed above can be ordered from:

  National Fire Protection Association
  1 Batterymarch Park
  Quincy, MA 02269-9101
  1-800-344-3555
  www.nfpa.org

- Carpenter, David. *Electrician's Technical Reference: Motor Controls.* Delmar Publishers, Inc. 2000.
- Early, Mark W., et al. *Illustrated Changes in the National Electrical Code.* Delmar Publishers, Inc. 2002.

  Provides a detailed view of the most important changes in the 2002 NEC

- Herman, Stephen L. *Electrician's Technical Reference: Industrial Electronics.* Delmar Publishers, Inc. 1999.
- Herman, Stephen L., *Industrial Motor Control*, 4th ed. Albany, NY: Delmar Publishers, 1999.
- Miller, Chris. *Illustrated Guide to the National Electrical Code,* 2nd ed. Delmar Publishers, Inc. 2002.

Conveniently groups Code requirements according to type of occupancy, and contains 600 illustrations

- Mullin, Ray and Robert Smith. *Electrical Wiring Commercial*, 11th ed. Delmar Publishers, Inc. 2002.
- Smith, Robert and Stephen Herman. *Electrical Wiring Industrial*, 11th ed. Delmar Publishers, Inc. 2002.
- Surbrook, Truman and Jonathan Althouse. *Interpreting the National Electrical Code*, 6th ed. Delmar Publishers, Inc. 2002.

Offer practical examples to illustrate how articles in the Code are applied

- Titus, Patricia A., et al. *Illustrated Dictionary for Electrical Workers*, 2nd ed. Delmar Publishers, Inc. 2002.

The publication(s) listed above can be ordered from:

Thompson Learning
Attn: Order Fulfillment
P.O. Box 6904
Florence, KY 41022
1-800-477-3692
www.delmar.com

Answers to Assignment Sheets

Assignment Sheet 1

Interpret Nameplate Information

	A	B
a.	30-hp	50-hp
b.	3-phase	3-phase
c.	1760-rpm	1670-rpm
d.	230/460-V	460-V
e.	Continuous	24-hrs
f.	40°C	45°C
g.	Thermal/magnetic	Thermal/magnetic
h.	D785516	7621
i.	60-Hz	60-Hz
j.	Induction	Induction
k.	Alternating Current	Alternating Current
l.	64/33-A	25-A
m.	1.15	1.15

Assignment Sheet 2

Describe Remedies for Common Motor Problems

A.
1. Check supply voltage
2. Check motor wiring with ohmmeter
3. Remove load from motor and try to start
4. Move motor shaft by hand to check for end play and bearing tightness

B.
1. Clean motor
2. Adjust belt tension
3. Check full load amperage
4. Check for correct voltage
5. Check for loose bearings
6. Check for tight bearings
7. Check pulley alignment
8. Check for bent shaft

C.
1. Replace out of balance pulley
2. Remove pulley and check straightness of shaft
3. Tighten motor accessories and mounting
4. Align drive pulley and driven pulley
5. Replace bearings
6. Clean motor
7. Check for out-of-round motor

D.
1. Use recommended motor bearing oil
2. Put clean oil in reservoir
3. Clean excessive grease buildup
4. Adjust belt
5. Move shaft by hand to check end and side play
6. Replace rough or worn bearings
7. Remove pulley and check for bent shaft
8. Align drive pulley with driven pulley

Answers to Assignment Sheets

Assignment Sheet 3

Use the *National Electrical Code* to Answer Questions About Motor Control Circuits

a. 430.72 (Also Article 240)
b. 1. Conductors that do not leave enclosure
   2. Conductors supplied by transformer

Note: These exceptions are found in 430.72.

c. No
d. Must be protected by raceway or enclosure
e. At time motor circuit is disconnected
f. A circuit designed for signaling and control of a motor starter
g. Conduit or raceway
h. A disconnecting means shall be located in sight from the controller location

Assignment Sheet 4

Distinguish Between Motor Starters and Contactors

a. Contactor
b. Motor starter
c. Contactor
d. Contactor
e. Motor starter
f. Contactor
g. A, C, D, F; contactors do not have thermal overloads (heaters), reset button, or overload contacts
h. B, E; motor starters do have thermal overloads (heaters), reset button, or overload contacts

Assignment Sheet 5

Answer Questions About Uses of Contactors and Motor Starters

A. 1. Motor starter
   2. Contactor
B. 1. Lighting loads
   2. Heaters
   3. Transformers
   4. Capacitors
   5. Power circuits
C. 1. Starting motors
   2. Reversing motors
   3. Braking motors to stop
   4. Controlling speed of motors
D. 1. Contactors do not provide running overload protection for motors
   2. Contactors are not designed for high inrush current for motor starting
   3. Contactors do not contain sets of overload contacts.

Written Test

Name ______________________________________

Date ____________________________ Score__________

Objective 1

Match the terms related to motors and controllers with their definitions. Write the correct numbers in the blanks.

1. Arc chute
2. Armature
3. Contactor
4. Delta
5. Dual voltage motor
6. Power factor
7. Relay
8. Shading coil
9. Single phasing
10. Starter
11. Thermal overloads
12. Torque
13. Wye

_____ a. Three-phase circuit in which the windings are connected in the shape of a "Y"

_____ b. Ratio of active power to apparent power

_____ c. Device used to make or break a motor's power circuit

_____ d. Partition between contacts to reduce electrical arcing

_____ e. Single turn of conducting material mounted on the magnetic assembly face to produce out-of-phase magnetic force

_____ f. Force that produces a rotating or twisting action

_____ g. Portion of coil assembly moved by magnetism

_____ h. Operated by a change in one electrical circuit to control a device in the same circuit or another circuit; used in control circuits

_____ i. Device used to sense current draw in a circuit and open a control circuit when its rating is exceeded

_____ j. Three-phase circuit in which the windings are connected in series to form a closed loop

_____ k. Motor capable of being wired to run at two different voltages

_____ l. Device used to make and break electrical power circuit

_____ m. Loss of one phase of a three-phase system

Written Test

Objective 2 List required motor nameplate information.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

g. ______________________________

h. ______________________________

i. ______________________________

Objective 3 Discuss direct current motor theory of operation.

a. ______________________________

____

b. ______________________________

____

c. ______________________________

____

Objective 4 List three types of DC motors.

a. ______________________________

b. ______________________________

c. ______________________________

Objective 5 Discuss single-phase motor theory of operation.

a. ______________________________

____

b. ______________________________

____

Objective 6

List five types of single-phase motors.

a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

Objective 7

Discuss three-phase motor theory of operation.

a. ____________________

____

b. ____________________

____

Objective 8

List three types of three-phase motors.

a. ____________________

b. ____________________

c. ____________________

Objective 9

State the procedure for reversing rotation of a three-phase motor.

____

____

____

Objective 10

Select from the following list typical supply voltages for three-phase motors by placing an "X" in the blanks next to each correct answer.

_____ a. 360-volt three-phase delta

_____ b. 240-volt three-phase delta

_____ c. 208-volt three-phase wye

_____ d. 240-volt three-phase wye

_____ e. 480-volt three-phase wye

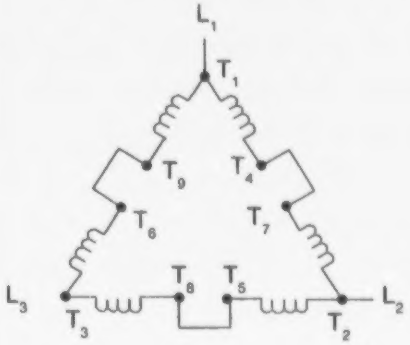
Written Test

Objective 11

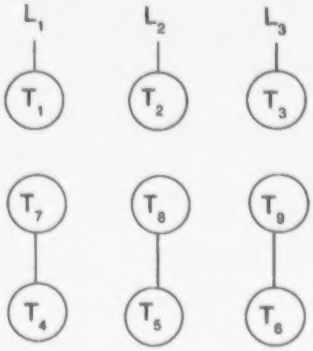
Identify schematics and terminal connections for delta- and wye-wound three-phase motors.

a. ______________________________

Schematic Connection

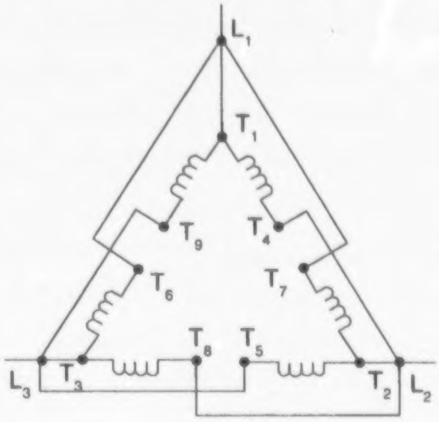

L_1
T_1
T_9
T_4
T_6
T_7
T_8
T_5
L_3
T_3
T_2
L_2

Terminal Connection

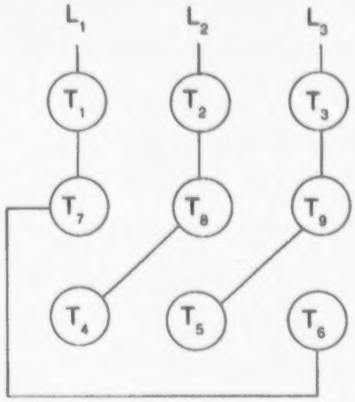

L_1
L_2
L_3
T_1
T_2
T_3
T_7
T_8
T_9
T_4
T_5
T_6

b. ______________________________

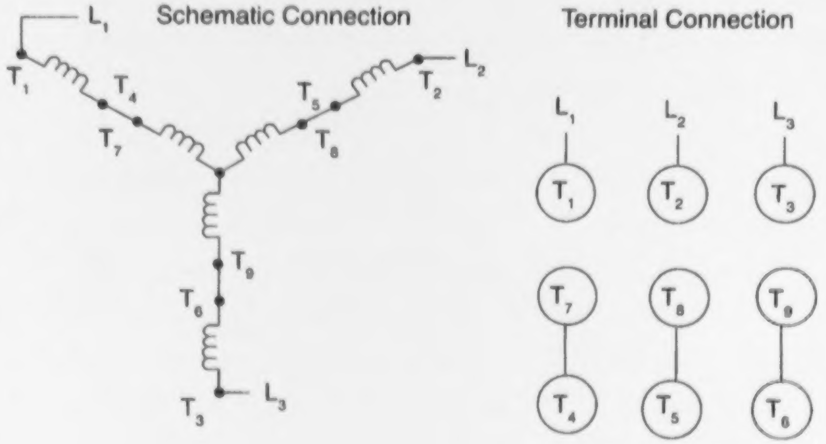
Schematic Connection


L_1
T_1
T_9
T_4
T_6
T_7
T_8
T_5
L_3
T_3
T_2
L_2

Terminal Connection


L_1
L_2
L_3
T_1
T_2
T_3
T_7
T_8
T_9
T_4
T_5
T_6

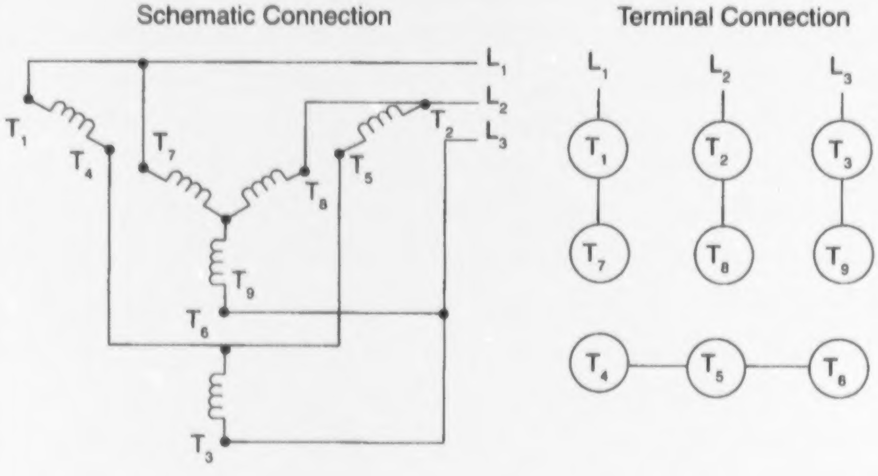
c. ______________________________


Schematic Connection

Terminal Connection

L_1
L_2
L_3
T_1
T_2
T_3
T_4
T_5
T_6
T_7
T_8
T_9

d. ______________________________


Schematic Connection

Terminal Connection

L_1
L_2
L_3
T_1
T_2
T_3
T_4
T_5
T_6
T_7
T_8
T_9

Written Test

Objective 12

Match motor problems with their typical symptoms.

Note: Blanks should contain more than one answer.

1. Obstruction of ventilating system
2. Lack of oil
3. Unbalanced parts
4. Overloading
5. Dirty oil
6. Bent shaft
7. Incorrect voltage
8. Excessive end thrust
9. Faulty alignment
10. High ambient temperature
11. Excessive grease or oil
12. Worn bearings
13. Blown fuse
14. Open overload
15. Excessive load

a. ______________________ Failure to start

b. ______________________ Excessive noise

c. ______________________ Overheated bearings

d. ______________________ Overheated motor

Objective 13

Match remedies with the correct symptoms of motor problems.

Note: Blanks should contain more than one answer.

1. Clean motor
2. Put clean oil in reservoir
3. Replace bearings
4. Adjust belt tension
5. Check for correct voltage
6. Check supply voltage
7. Check full load amperage
8. Check motor wiring with ohmmeter

a. ______________________ Failure to start

b. ______________________ Excessive noise

c. ______________________ Overheated bearings

d. ______________________ Overheated motor

Objective 14

Complete the following safety rules to observe when working around motors.

a. Do not underestimate the ________________ of the circuit.

b. Never install equipment that will ________________ the circuit.

c. Never bypass ________________ devices.

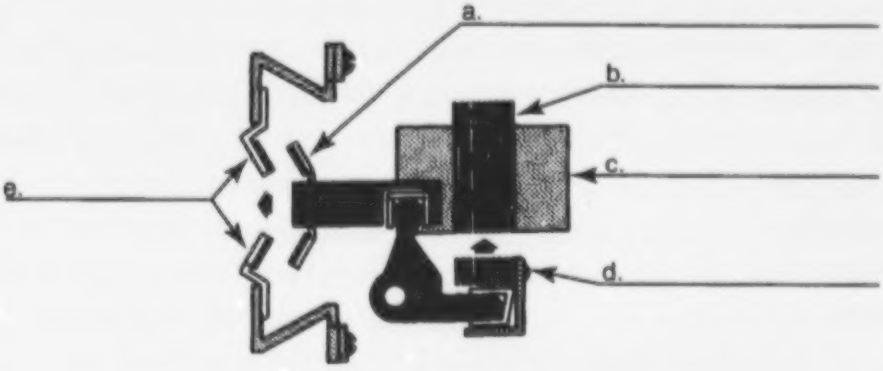
d. Protect all ________________ from physical and thermal hazards.

e. ________________ and ________________ electrical disconnects when working on motors or motor circuits.

f. ________________ all electric motor frames.

Objective 15

Identify the parts of the magnetic contactor illustrated below. Write your answers in the blanks provided.



Objective 16

Select from the following list electrical devices or circuits controlled by contactors by placing an "X" in the blanks next to each correct answer.

_____ a. Starting buttons

_____ b. Lighting loads

_____ c. Heaters

_____ d. Transformers

_____ e. Overload contacts

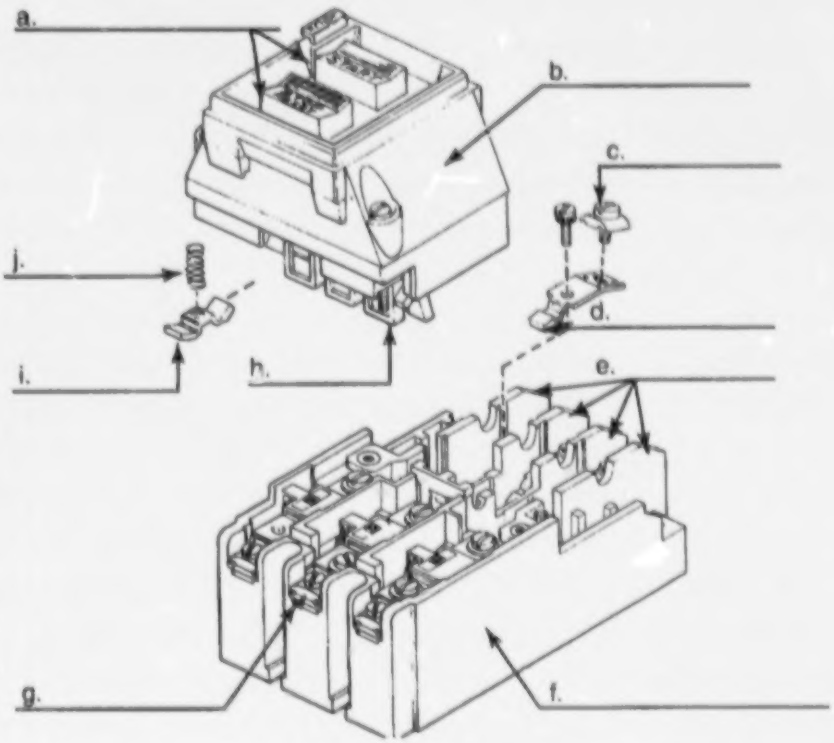
_____ f. Capacitors

_____ g. Power circuits

Written Test

Objective 17

Identify the parts of the manual motor starter illustrated below. Write your answers in the blanks provided.



Objective 18

Name two types of motor starters.

a. ____________________

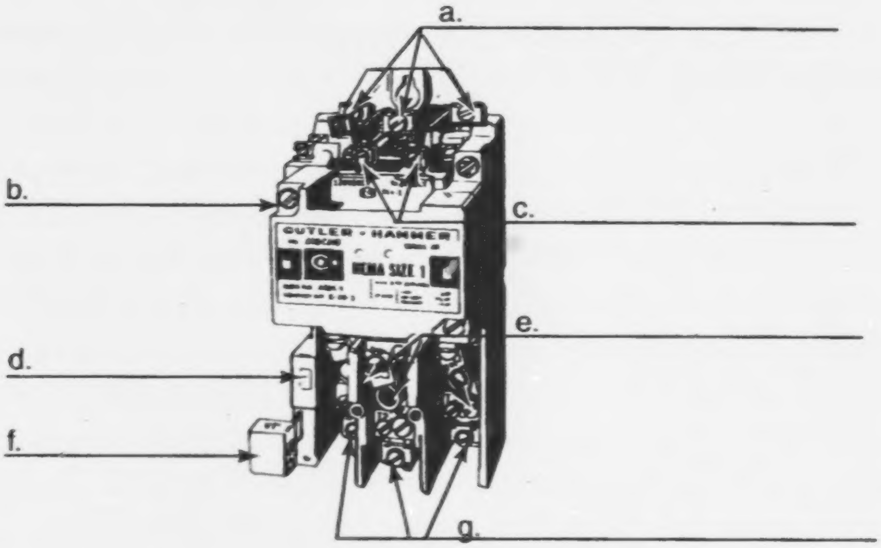
b. ____________________

Written Test

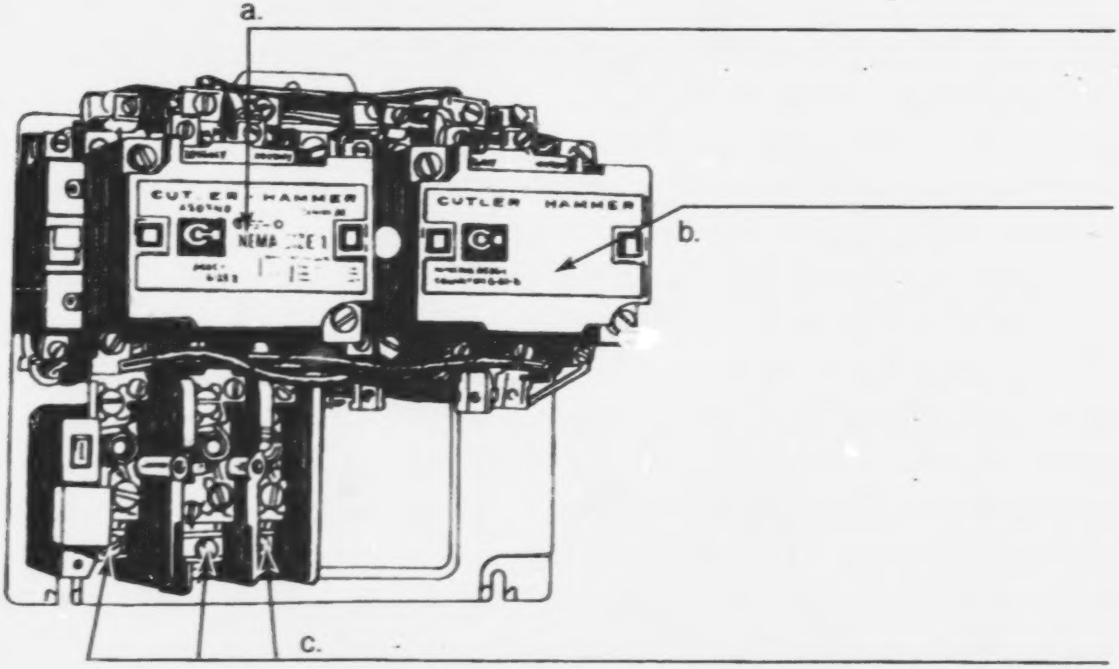
Objective 19

Identify the parts of the magnetic motor starters illustrated below. Write your answers in the blanks provided.

A.


a.
b.
c.
CUTLER - HAMMER
NEMA SIZE 1
e.
d.
f.
g.

B.


a.
CUTLER - HAMMER
NEMA SIZE 1
CUTLER HAMMER
b.
c.

Written Test

Objective 20

List three uses of magnetic motor starters.

a. ____________________

b. ____________________

c. ____________________

Objective 21

Compare parts in magnetic contactors with parts in magnetic motor starters by wiring "yes" or "no" in the correct column for each part.

Parts	Contactors	Motor Starters
a. Overload contact		
b. Line terminals		
c. Reset button		
d. Power contacts		
e. Thermal overload (heater)		
f. Load terminals		
g. Coil		
h. Holding contacts		

Objective 22

Complete the following statements concerning reasons a contactor cannot be used to control a motor.

a. A contactor does not provide running ____________________ ____________________ for the motor.

b. A contactor is not designed for ____________________ ____________________ ____________________ for motor starting.

c. A contactor does not contain a set of ____________________ ____________________.

Objective 23

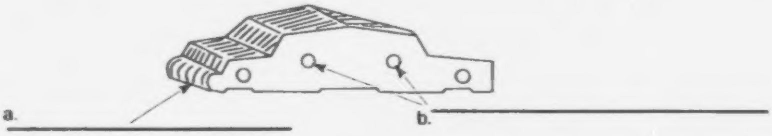
State the purposes of a coil assembly.

a. ____________________

b. ____________________

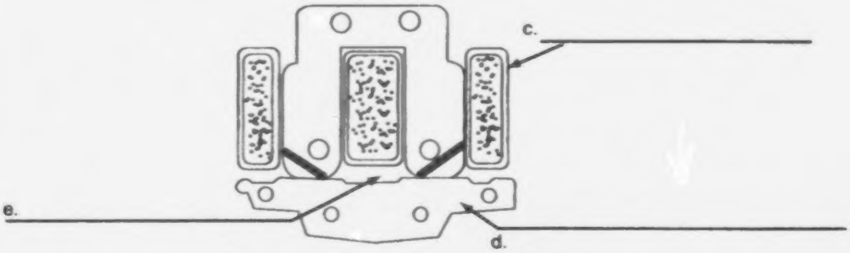
Objective 24

Identify the parts of the coil assembly illustrated below. Write your answers in the blanks provided.



a. ______________________

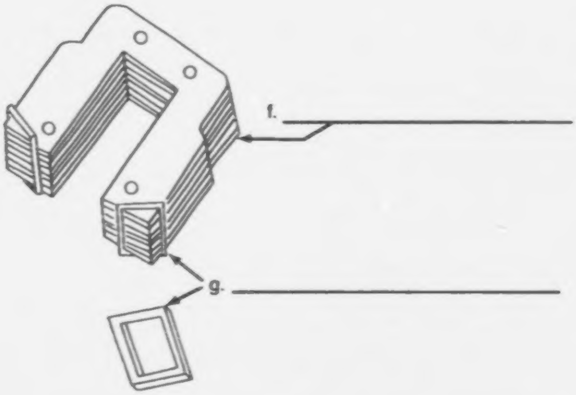
b. ______________________



c. ______________________

d. ______________________

e. ______________________



f. ______________________

g. ______________________

*Permission to duplicate this test is granted.

Answers to Written Test

Objective 1

a. 13
b. 6
c. 10
d. 1
e. 8
f. 12
g. 2
h. 7
i. 11
j. 4
k. 5
l. 3
m. 9

Objective 2

Answers may be listed in any order.

a. Manufacturer
b. Rated voltage
c. Full-load amperes
d. Rated frequency
e. Number of phases
f. Rated full-load speed
g. Rated ambient temperature
h. Time (duty) rating
i. Rated horse power

Objective 3

a. A magnetic field is produced at the face of the stationary poles.
b. A magnetic field is produced in the armature windings.
c. The fields repel each other causing the armature to rotate.

Objective 4

a. Shunt motor
b. Series motor
c. Compound motor

Objective 5

a. The motor operates on a single wave form from a two-wire A/C system.
b. A/C single phase current produces a varying magnetic field.

Objective 6

a. Shaded pole
b. Split phase
c. Capacitor
d. Induction repulsion
e. Series

Objective 7

a. Current in the stator produces a rotating magnetic field.
b. Currents induced in the rotor create a magnetic field.
c. The rotor turns, seeking an opposite pole.

Objective 8

a. Squirrel cage induction
b. Wound rotor
c. Synchronous

Objective 9

A three-phase motor is reversed by interchanging any two of the three supply lines anywhere between the motor and the source of supply.

Answers to Written Test

Objective 10	b, c
Objective 11	a. Delta-wound 9-lead high voltage b. Delta-wound 9-lead low voltage c. Wye-wound 9-lead high voltage d. Wye-wound 9-lead low voltage
Objective 12	a. 7, 12, 13, 14, 15 b. 3, 6, 9, 12 c. 2, 5, 6, 8, 11, 12 d. 1, 2, 4, 7, 10, 14, 15
Objective 13	a. 6, 8 b. 1, 3 c. 2, 3, 4 d. 1, 4, 5, 7
Objective 14	a. Danger b. Overload c. Protective d. Wires e. Tag, lock f. Ground
Objective 15	a. Movable contacts b. Frame c. Coil d. Armature e. Stationary contacts
Objective 16	a. b, c, d, f, g
Objective 17	a. Start/stop buttons b. Insulated operating mechanism enclosure c. Saddle clamp terminal for power input circuit d. Stationary contact e. Arc chutes f. Insulated contactor main frame g. Saddle clamp terminals for power output circuit h. Insulated T-frame assembly i. Movable contacts j. Spring
Objective 18	a. Manual b. Magnetic

Objective 19

A. a. Line terminals
b. Auxiliary contacts
c. Coil terminals
d. Housing for overload contacts
e. Thermal overloads
f. Reset button
g. Load terminals

B. a. Forward starter
b. Reverse starter
c. Thermal overloads

Objective 20

Any three of the following:

a. Starting motors
b. Reversing motors
c. Braking motors to stop
d. Controlling speed of motors

Objective 21

	Contactors	**Starters**
a.	No	Yes
b.	Yes	Yes
c.	No	Yes
d.	Yes	Yes
e.	No	Yes
f.	Yes	Yes
g.	Yes	Yes
h.	Yes	Yes

Objective 22

a. Overload protection
b. High inrush current
c. Overload contacts

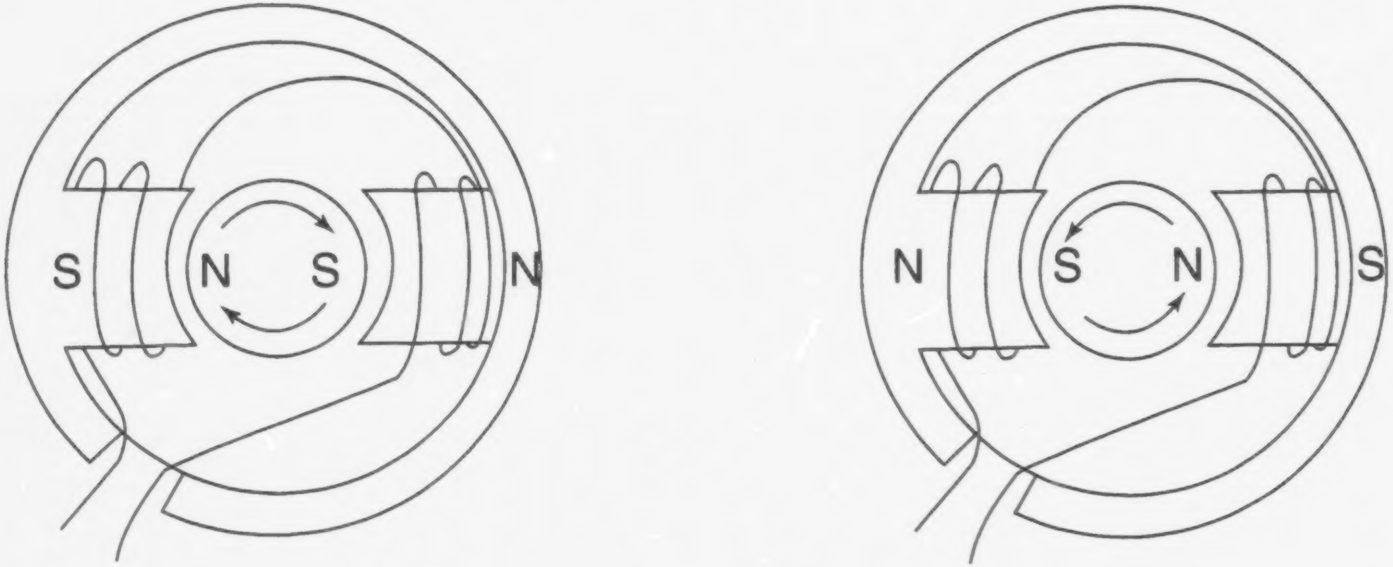
Objective 23

a. To change an electrical signal to a magnetic signal
b. To activate the mechanical portion of the motor starter

Objective 24

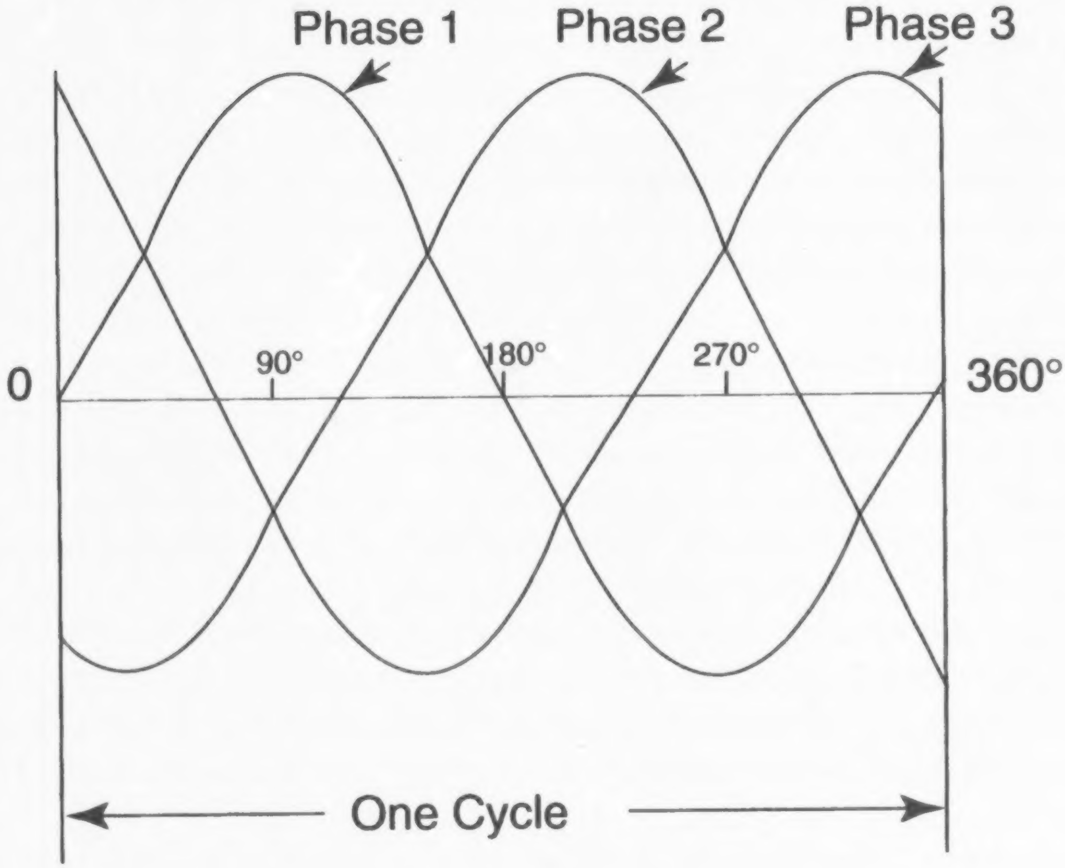
a. Laminations
b. Rivets
c. Magnetic coil
d. Armature
e. Air gap
f. Magnetic assembly
g. Shading coil

Magnetic Poles in an Electric Motor



Reversing direction of current flow reverses magnetic polarity of poles.

Poly-Phase Magnetism

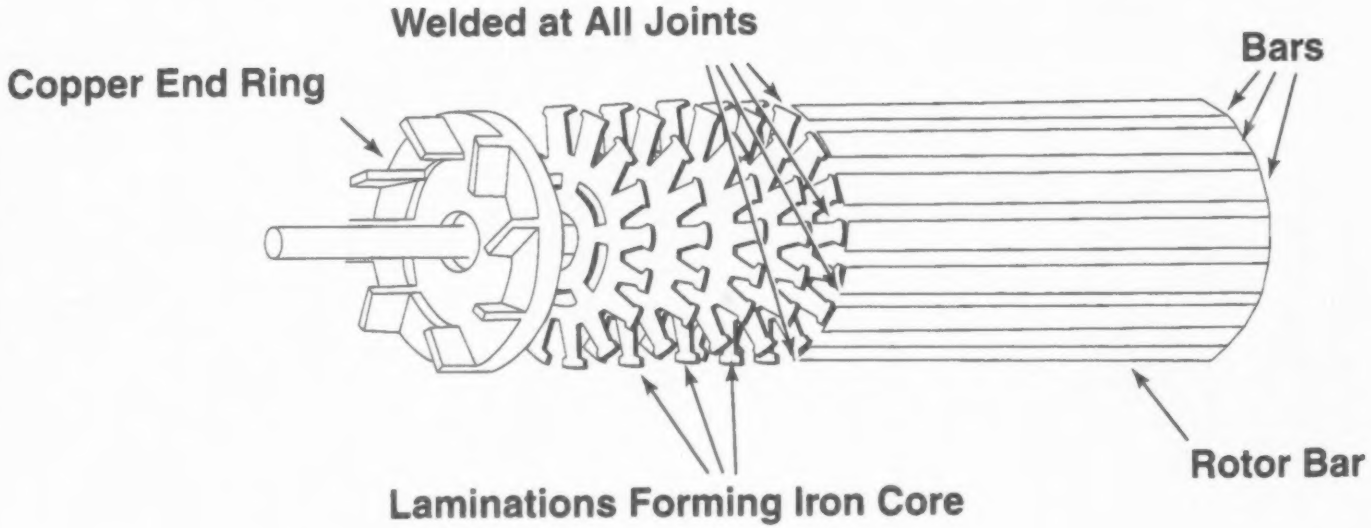

Phase 1
Phase 2
Phase 3
0
90°
180°
270°
360°
One Cycle

As each phase sine wave changes in magnitude and direction, so does the strength of the magnetic field it induces.

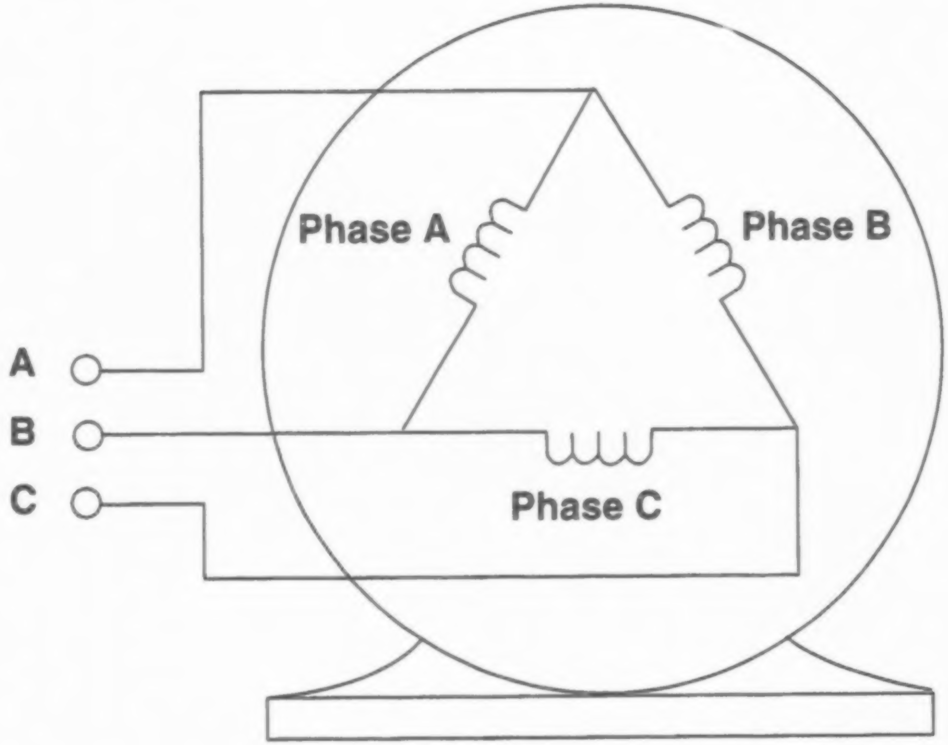
When one sine wave is zero, the other two are 86.6% of their positive or negative maximums.

When any two are equal in magnitude and direction, the remaining third has the opposite polarity and a peak/maximum value.

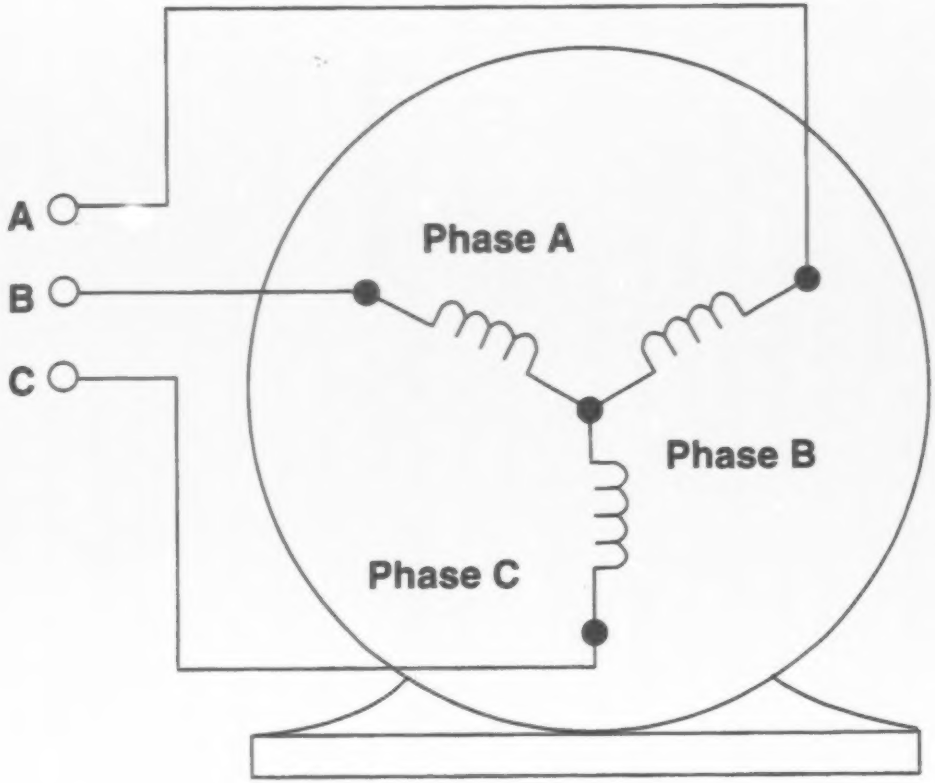
Squirrel-Cage Rotor


Welded at All Joints
Bars
Copper End Ring
Rotor Bar
Laminations Forming Iron Core

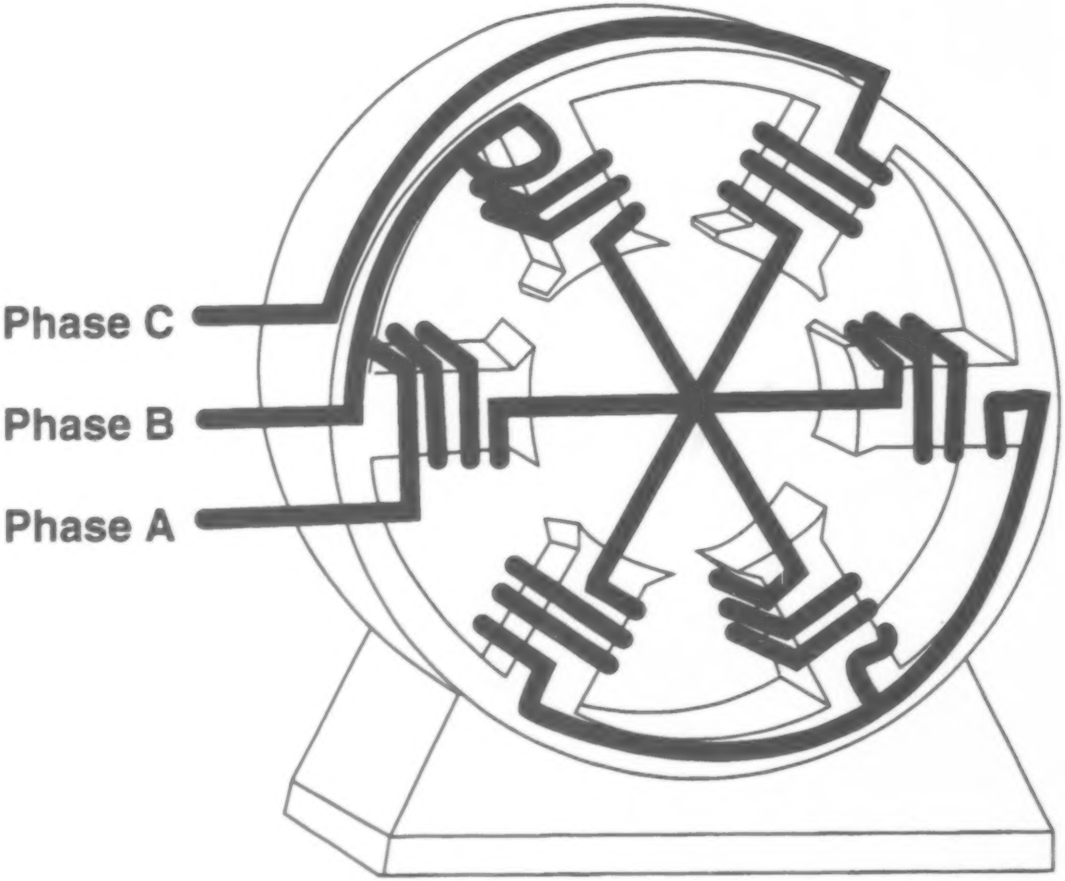
Delta-Wound Motor


Phase A
Phase B
Phase C
A
B
C

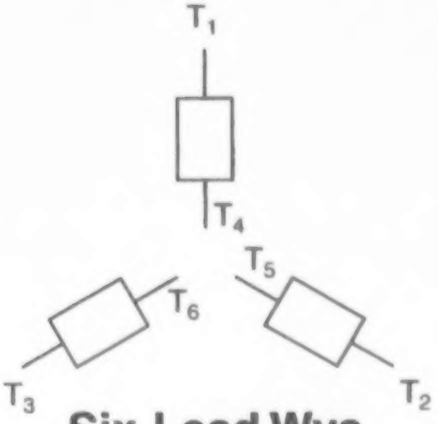
Wye-Wound Motor (Single Speed)


A
B
C
Phase A
Phase B
Phase C

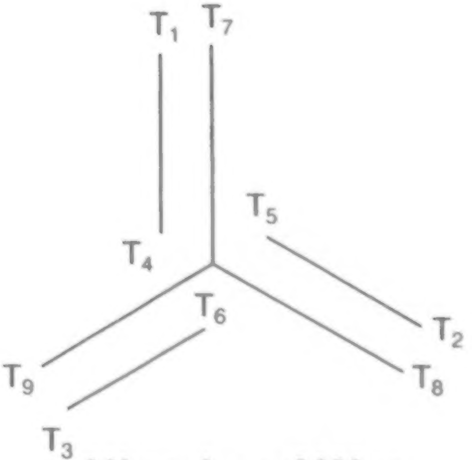
Three-Phase Motor Windings


Phase C
Phase B
Phase A

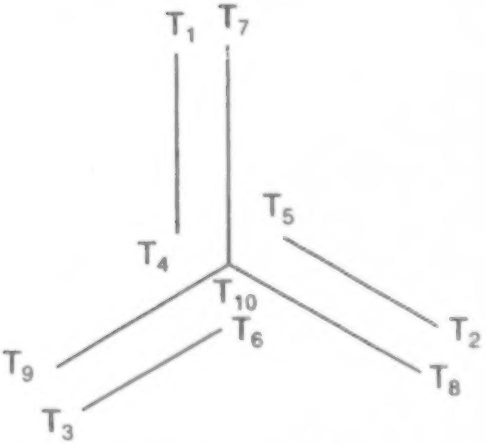
Dual Voltage Three-Phase Motor Showing Possible Six, Nine, and Ten Leads


T_1
T_4
T_5
T_6
T_3
T_2

Six-Lead Wye

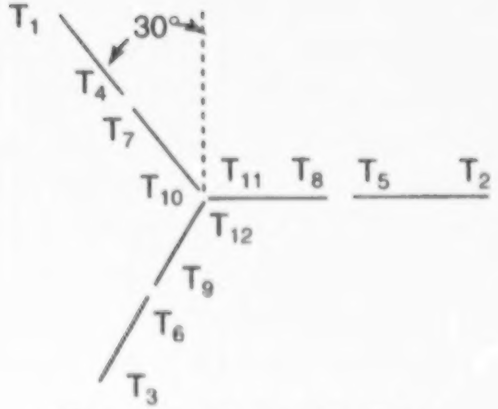

T_1
T_7
T_5
T_4
T_6
T_2
T_9
T_8
T_3

Nine-Lead Wye

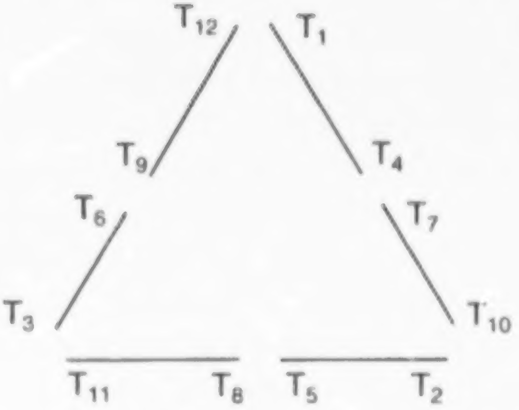

T_1
T_7
T_5
T_4
T_{10}
T_6
T_2
T_9
T_8
T_3

Ten-Lead Wye

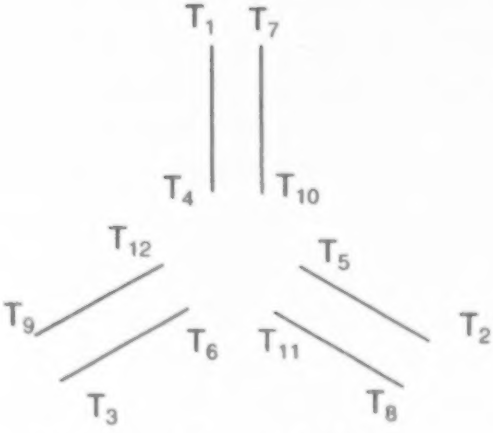
Dual Voltage Three-Phase Motor Showing Possible Twelve Leads


T1
30°
T4
T7
T10
T11
T8
T5
T2
T12
T9
T6
T3

Twelve-Lead Wye (High Voltage)


T12
T1
T9
T4
T6
T7
T3
T10
T11
T8
T5
T2

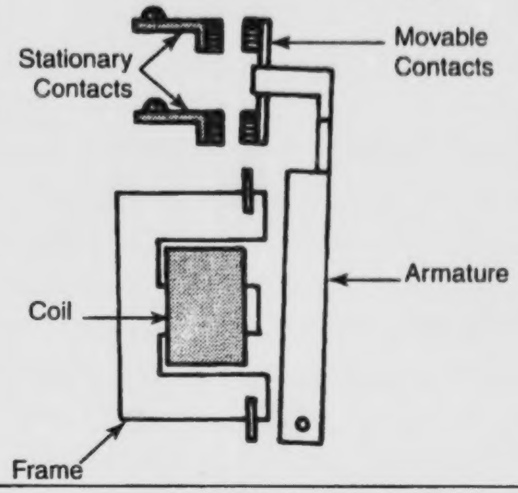
Twelve-Lead Delta (High Voltage)

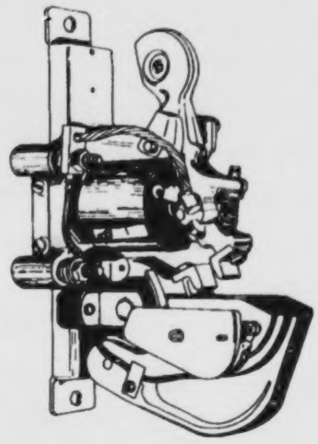

T1
T7
T4
T10
T12
T5
T9
T6
T11
T2
T3
T8

Twelve-Lead Wye (Low Voltage)

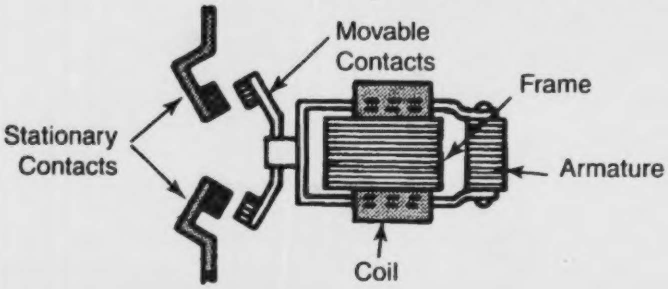
Types of Magnetic Contactor Assemblies

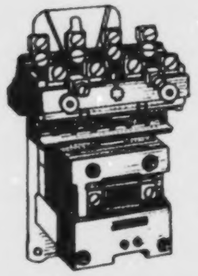
Clapper


Stationary Contacts
Movable Contacts
Armature
Coil
Frame

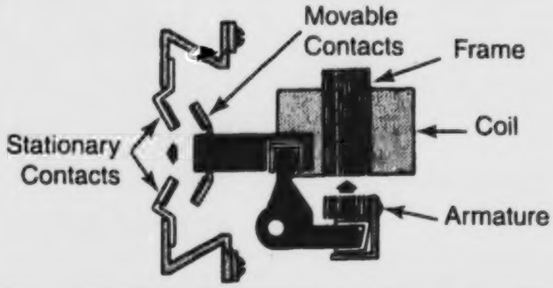


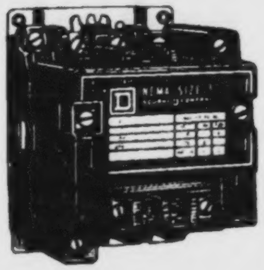
Horizontal Action


Movable Contacts
Frame
Stationary Contacts
Armature
Coil



Bell Crank


Movable Contacts
Frame
Coil
Stationary Contacts
Armature



Adapted with permission of Cutler-Hammer Products/Eaton Corp.; Allen-Bradley, a Rockwell International Company, Milwauke, Wisconsin; and courtesy of Square D Company.

TM 9

Unit Contents

Teacher Page

Teacher Components

Suggested Activities 8–3
Answers to Assignment Sheets 8–7
Written Test 8–9
Answers to Written Test 8–13

Student Page

Student Components

Learning Activities Sheet 8–3
Objective Sheet 8–5
Information Sheet 8–7

* Assignment Sheets

1—Construct a Basic Ladder Diagram 141
2—Identify Electrical Symbols in a Wiring Diagram 143

* Assignment Sheets are located in Student Workbook 1.

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make copies of any teacher supplements that will be provided for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Have students complete the focus assignment to introduce topics presented in unit of instruction.

Suggested Activities

- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheets. Review with students the criteria for evaluation of these activities.
- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Provide students with examples of wiring and ladder diagrams.
- Have students evaluate sequence of operation of various ladder diagrams. Skill area: problem solving.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the assignment sheets. Rate the student using the criteria listed on each assignment sheet. See Answers to Assignment Sheets for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.
- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Kaltwasser, Stan and Gary Flowers. *Commercial and Industrial Wiring.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.
- Rockis, Gary and Glen Mazur. *Electrical Motor Controls*, 2nd Ed. Alsip, IL: American Technical Publishers, 1987.
- Teague, Cash and Garner Pewewardy. *Industrial Electricity: In-Plant Distribution.* Stillwater, OK: Oklahoma Curriculum and Instructional Materials Center, 1984.

Suggested Supplemental Resources

Print Media

- *2002 NEC Analysis of Changes.* Quincy, MA: National Fire Protection Association, 2001.

  Provides a detailed view of the most important changes in the 2002 NEC

- *NEC 2002 Handbook.* Quincy, MA: National Fire Protection Association, 2001.

  Contains complete Code text plus commentary, photos, and full-color graphics

- *National Electrical Code, 2002.* Quincy, MA: National Fire Protection Association, 2001.

  The publication(s) listed above can be ordered from:

  National Fire Protection Association
  1 Batterymarch Park
  Quincy, MA 02269-9101
  1-800-344-3555
  www.nfpa.org

- Early, Mark W., et al. *Illustrated Changes in the National Electrical Code*. Delmar Publishers, Inc. 2002.

  Provides a detailed view of the most important changes in the 2002 NEC

- Herman, Stephen L. *Electrician's Technical Reference: Industrial Electronics.* Delmar Publishers, Inc. 1999.

- Miller, Chris. *Illustrated Guide to the National Electrical Code,* 2nd ed. Delmar Publishers, Inc. 2002.

  Conveniently groups Code requirements according to type of occupancy, and contains 600 illustrations

- Mullin, Ray and Robert Smith. *Electrical Wiring Commercial,* 11th ed. Delmar Publishers, Inc. 2002.

- Smith, Robert and Stephen Herman. *Electrical Wiring Industrial*, 11th ed. Delmar Publishers, Inc. 2002.

- Surbrook, Truman and Jonathan Althouse. *Interpreting the National Electrical Code,* 6th ed. Delmar Publishers, Inc. 2002.

  Offer practical examples to illustrate how articles in the Code are applied

- Titus, Patricia A., et al. *Illustrated Dictionary for Electrical Workers,* 2nd ed. Delmar Publishers, Inc. 2002.

The publication(s) listed above can be ordered from:

Thompson Learning
Attn: Order Fulfillment
P.O. Box 6904
Florence, KY 41022
1-800-477-3692
www.delmar.com

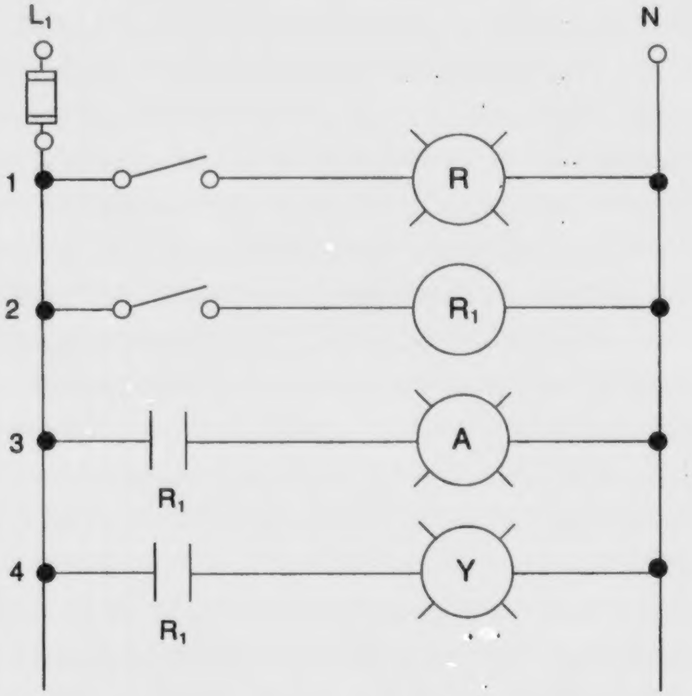
Electronic Media

- Electrical Construction and Maintenance (Magazine) www.ecmweb.com

Answers to Assignment Sheets

Assignment Sheet 1

Construct a Basic Ladder Diagram



Assignment Sheet 2

Identify Electrical Symbols in a Wiring Diagram

a. Normally open push button (start)
b. Normally closed push bottom (stop)
c. Thermal overload relay
d. Auxiliary contact
e. Line and control wiring terminal
f. Main contact
g. T_2 motor lead terminal
h. Three-phase motor
i. Overload device switch

Written Test

Name ______________________________

Date ______________________ Score __________

Objective 1

Match the terms related to electrical diagrams and symbols with their definitions. Write the correct numbers in the blanks. Definitions continue on the next page.

1. Across-the-line
2. Automatic starting
3. Auxiliary contact
4. Bimetal
5. Contactor
6. Full voltage control
7. Jogging
8. Ladder diagram
9. Magnetic contactor
10. Multispeed starter
11. One-line diagram
12. Overload relay
13. Push button
14. Relay
15. Remote control
16. Selector switch
17. Starter
18. Timer
19. Wiring diagram

_____ a. Pilot device that delays closing or opening of a circuit for a specific time; may be motor driven, solenoid-actuated, or electric

_____ b. Control device with electric contactor and overload protection; designed to protect motor from voltage inrush during starting

_____ c. Manually operated multiposition switch

_____ d. Contactor operated electromechanically

_____ e. Momentarily operating; moving driven machine a small distance

_____ f. Device that controls electrical apparatus from some distance

_____ g Switch, manually operable plunger, button, or actuating device

_____ h. Function of magnetic control that connects equipment directly to supply line on starting

_____ i. Electromechanical device operated by a coil; uses contacts to make or break circuits

_____ j. Device for protecting motor from overload current or voltage

_____ k. Starter designed to start motor at a reduced speed and build to full speed in preset steps

_____ l. Device without overload protection; repeatedly establishes and interrupts an electric power circuit

_____ m. Two different metals bonded to provide fast heat transfer to trip contacts by mechanical deflection

_____ n. Consists of symbols and lines that indicate all connections and placement of all component parts in a device or circuit, including the power circuit wiring

_____ o. Schematic consisting of single-phase and three-phase power lines; indicates power distribution, and fuse and interrupter coordination

_____ p. Contact provided in addition to the main circuit contacts but operated with the main contacts

_____ q. Method of starting an electric motor by connecting it directly to supply line

_____ r. Pertaining to self-acting starter completely controlled by pilot switches or some other sensing device

_____ s. Schematic consisting of symbols and lines that indicate power source and how current flows through various parts of control circuit

Objective 2

Complete the following characteristics of wiring diagrams.

_____ a. They show components in their ________________ locations.

_____ b. They provide a ________________ for field wiring.

_____ c. They use standard electrical ________________.

_____ d. They show ________________ and ________________ lines together.

_____ e. They make circuits difficult to ________________ .

Objective 3

Select true statements concerning characteristics of ladder diagrams by placing an "X" in the blanks next to the true statements.

_____ a. They resemble a ladder.

_____ b. The depict individual circuits as ladder rungs.

_____ c. They use mechanical symbols.

_____ d. They show power and control voltages together.

_____ e. They simplify circuit troubleshooting.

Objective 4

State the characteristics of one-line diagrams.

a. ____________________

b. ____________________

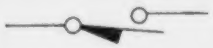
c. ____________________

d. ____________________

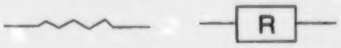
e. ____________________

Objective 5

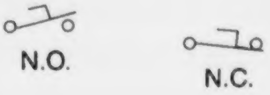
Identify the wiring and ladder diagram symbols shown below. Write your answers in the blanks provided.



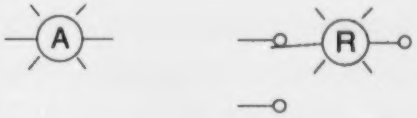
a. ____________________



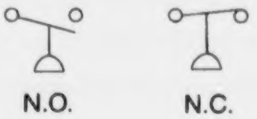
b. ____________________



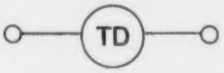
c. ____________________



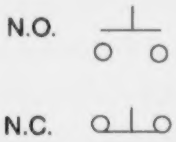
d. ____________________



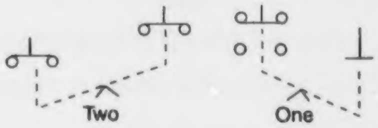
e. ____________________



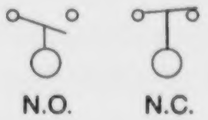
f. ____________________



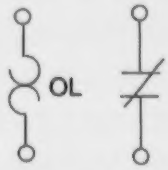
g. ____________________



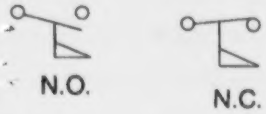
h. ____________________



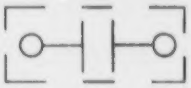
i. ______________________



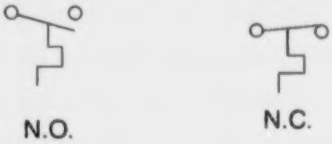
j. ______________________



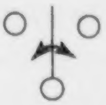
k. ______________________



l. ______________________



m. ______________________



n. ______________________

Objective 6

Arrange in order the major steps in constructing a ladder diagram by placing the correct sequence numbers in the appropriate blanks.

_____ a. Identify and label loads.

_____ b. Connect circuit wires, keeping ladder rungs an equal distance apart for ease of reading.

_____ c. Establish and label power lines.

_____ d. Identify and label control devices and contacts for each circuit (rung).

_____ e. Number rungs, and cross reference.

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a. 18
b. 17
c. 16
d. 9
e. 7
f. 15
g. 13
h. 6
i. 14
j. 12
k. 10
l. 5
m. 4
n. 19
o. 11
p. 3
q. 1
r. 2
s. 8

Objective 2

a. Approximate
b. Guide
c. Symbols
d. Power, control
e. Trace

Objective 3

a, b, e

Objective 4

a. They show the location of transformers.
b. They show the location of overcurrent devices.
c. They indicate overcurrent device sizes.
d. They indicate sizes of loads.
e. They indicate characteristics of loads.

Objective 5

a. Limit switch (normally open)
b. Standard resistor
c. Foot switches
d. Pilot lights
e. Pressure and vacuum switches
f. Time delay relay coil
g. Momentary contact
h. Maintained contacts
i. Liquid level switch
j Thermal overload relay
k. Flow switch
l. Two-wire pilot device
m. Temperature-actuated switch
n. Plugging switch

Objective 6

a. 2
b. 4
c. 1
d. 3
e. 5

Unit 9 Two- and Three-Wire Controls

Unit Contents

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Answers to Written Test 9–15

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* Assignment Sheets

1—Complete a Ladder Diagram and a Wiring Diagram of a Two-Wire Control Using a Thermal Switch 145
2—Draw a Ladder Diagram of a Three-Wire Control with an "On" Indicating Pilot Light 147
3—Draw a Ladder and a Wiring Diagram of a Three-Wire Control with an "Off" Indicating Pilot Light 149
4—Determine the Number and Size of Conductors Needed to Operate a Two-Wire Control System 151
5—Determine the Number and Size of Conductors Needed to Operate a Three-Wire Control System 153

* Job Sheets

1—Wire a Two-Wire Control 155
2—Wire Two Float Switches to Operate a Starter (series connection) 159
3—Wire Two Float Switches to Operate a Starter (parallel connections) 163
4—Wire a Pressure Switch to Operate a Starter with "On" and "Off" Pilot Lights 167
5—Wire A Three-Wire Control System 171
6—Wire a Multiple Station Three-Wire Control 175
7—Wire a Multiple Station Three-Wire Control with "On" and "Off" Pilot Lights 179

* Assignment Sheets and Job Sheets are located in Student Workbook 2.

Instructional Plan

Suggested Activities

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
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- Make copies of any teacher supplements that will be provided for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Have students complete the focus assignment to introduce topics presented in unit of instruction.

Suggested Activities

- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheets. Review with students the criteria for evaluation of these activities.
- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Tour an industrial facility utilizing two-wire and three-wire controls Discuss with the class observations made during the tour.
- Show students various two-wire pilot devices.
- Invite an industrial maintenance technician to speak to the class. Conduct a question and answer session following the presentation.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the assignment sheets. Rate the student using the criteria listed on each assignment sheet. See Answers to Assignment Sheets for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.
- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

Suggested Activities

Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

Sample A

4—**Skilled**—Can perform job with no additional training.
3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
1—**Unskilled**—Is familiar with process, but is unable to perform job.
0—**No exposure**—No information or practice provided during training program.

Sample B

Yes—Can perform job with no additional training.
No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

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Suggested Activities

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Answers to Assignment Sheets

Assignment Sheet 1

Complete a Ladder Diagram and a Wiring Diagram of a Two-Wire Control Using a Thermal Switch—Both diagrams should be complete and legibly drawn showing a two-wire control using a thermal switch.

Assignment Sheet 2

Draw a Ladder Diagram of a Three-Wire Control with an "On" Indicating Pilot Light—The ladder diagram should show all components and be legibly drawn.

Assignment Sheet 3

Draw a Ladder and a Wiring Diagram of a Three-Wire Control with an "Off" Indicating Pilot Light—Both diagrams should be complete and legibly drawn showing a three-wire control with an "off" indicating pilot light and necessary auxiliary contacts.

Assignment Sheet 4

Determine the Number and Size of Conductors Needed to Operate a Two-Wire Control System

a. ½ inch (16) EMT; 3 conductors; #12 or #14 AWG THWN
b. ½ inch (16) EMT; 2 conductors; #12 or #14 AWG THWN
c. ½ inch (16) EMT; 3 conductors; #12 or #14 AWG THWN
d. 10 amperes

Assignment Sheet 5

Determine the Number and Size of Conductors Needed to Operate a Three-Wire Control System

a. ½ inch (16) EMT; 3 conductors; #12 AWG TW
b. ½ inch (16) EMT; 4 conductors; #12 AWG THWN
c. ½ inch (16) EMT; 7 conductors; #12 AWG TW
d. ½ inch (16) EMT; 3 conductors; #12 AWG TW
3. 20 amperes

Written Test

Name ____________________

Date ____________________ Score __________

Objective 1

Match the terms related to two- and three-wire controls with their definitions. Write the correct numbers in the blanks.

1. Auxiliary contacts
2. Indicating pilot light
3. Low voltage protection
4. Low voltage release
5. Pilot device
6. Three-wire control
7. Two-wire control

_____ a. Any type of switch having definite "on" and "off" positions that are used to control a magnetic starter or contactor

_____ b. Set of normally open or normally closed contacts on a starter, contactor or relay that close or open when main contacts close or open

_____ c. Small light that indicates status of controls or machinery

_____ d. Uses momentary contact; start/stop stations and a memory circuit interlock, connected in parallel with the start button to maintain the circuit

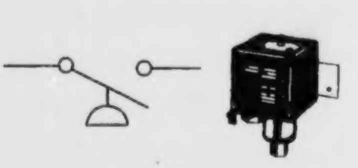
_____ e. Magnetic control only; nonautomatic restarting; three-wire control; power failure disconnects service; power restored by manual restart

_____ f. Directs operation of another device; alters the electrical circuit

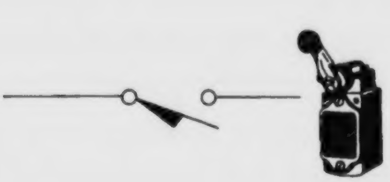
_____ g. Manual and magnetic control; automatic restarting; two-wire control; power failure disconnects service; when power is restored, the controller automatically restarts motor

Objective 2

Identify the typical two-wire pilot devices shown below. Write your answers in the blanks provided.

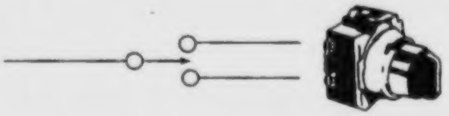


a. ____________________

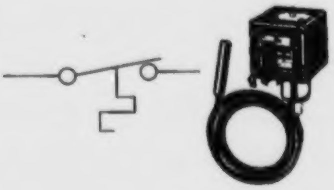


b. ____________________

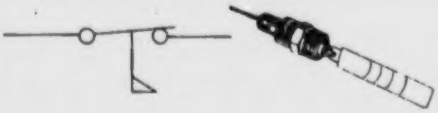
Written Test



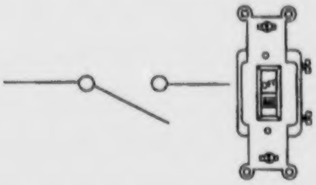
c. ______________________



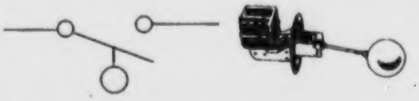
d. ______________________



e. ______________________



f. ______________________



g. ______________________

Objective 3 List two advantages of two-wire controls.

a. ____

b. ____

Objective 4 State the basic rule for three-wire controls.

____

____

____

Objective 5 List two advantages of three-wire controls.

a. ____

b. ____

Objective 6

Describe the operation of a two-wire control system.

Objective 7

Describe the operation of a three-wire control system.

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a. 7
b. 1
c. 2
d. 6
e. 3
f. 5
g. 4

Objective 2

a. Pressure switch
b. Limit switch
c. Selector switch
d. Thermal switch
e. Flow switch
f. Toggle switch
g. Float switch

Objective 3

a. Provide low voltage release
b. Do not require a human operator

Objective 4

Stop buttons are in series with auxiliary contacts and start buttons are in parallel with auxiliary contacts.

Objective 5

a. Provide low voltage protection
b. Allow for easy installation of indicating pilot lights

Objective 6

When the two-wire device is closed through some type of mechanical action, it allows current to flow to the starter's coil, energizing the coil and causing the starter to close.

Objective 7

When start button is depressed, current flows to the coil where the armature pulls in, closes auxiliary contacts, and seals around the start button.

Unit Contents

Teacher Components

Teacher Page

Suggested Activities 10–3
Answers to Assignment Sheets 10–9
Written Test 10–11
Answers to Written Test 10–13

Student Components

Student Page

Learning Activities Sheet 10–3
Objective Sheet 10–5
Information Sheet 10–7

* Assignment Sheets

1—Read and Interpret Ladder Diagrams Using Separate Control Circuits 183
2—Answer Questions About Control Circuits 187
3—Determine the Size and Number of Conductors Needed to Operate a Separate Control Circuit 189

* Job Sheets

1—Wire a Relay and a Load with a Separate Control Circuit 191
2—Wire a Three-Phase Starter to Operate by a Separate Control Circuit 195

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Suggested Activities

Instructional Plan

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- Read the unit carefully and plan for instruction.
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Suggested Activities

- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
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- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

-
- Visit the machine tool lab to view separate control circuits in use on machines. Have students take notes and participate in a class discussion of their observations.
- Visit a local industry that has a motor control center. Encourage students to ask about what they see.
- Show students control transformers, time clocks, push-to-test lights, etc. Allow students to become familiar with these devices.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
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Suggested Activities

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Answers to Assignment Sheets

Assignment Sheet 1

Read and Interpret Ladder Diagrams Using Separate Control Circuits

The correct sequence of operation for all three diagrams should be described.

Assignment Sheet 2

Answer Questions About Control Circuits

a. Yes—430.72 Table, 430-72(B) Column C
b. No—430.74(B)
c. No—430.74(A), 430.102(A)
d. 500%—430.72(C)(4)

Assignment Sheet 3

Determine the Size and Number of Conductors Needed to Operate a Separate Control Circuit

a. 3 conductors; #12 AWG
b. 2 conductors; #14 AWG
c. 2 conductors; #14 AWG
d. 3 conductors; #12 AWG
e. 15 amps

Written Test

Name ______________________________

Date ______________________ Score __________

Objective 1

Match the terms related to separate control circuits with their definitions. Write the correct numbers in the blanks.

1. Control transformer
2. Lightning arrestor
3. Motor control center
4. Push-to-test pilot light
5. Time clock
6. Under voltage relay

_____ a. Large panel used in industrial applications to centrally locate motor starters, motor branch circuit short circuit and ground fault protective devices, and motor branch circuit disconnecting means

_____ b. An electromechanical or electronic switch designed to control electrical circuits and equipment based on preset times of day

_____ c. Small transformer used to step supply voltage down to appropriate control voltage

_____ d. Used to indicate "on" and "off" status of motor and to verify condition by means of indicating a burned out lamp

_____ e. Relay whose coils are connected between the line terminals of motor branch circuit; opens a set of N/O contacts if one or more phases is lost

_____ f. Device connected to the supply side of a system, designed to absorb transient surges

Objective 2

List two reasons for separate control circuits.

a. ______________________________

b. ______________________________

Objective 3

List three applications for separate control circuits.

a. ______________________________

b. ______________________________

c. ______________________________

Objective 4

List two sources of separate control circuits.

a. ______________________________

b. ______________________________

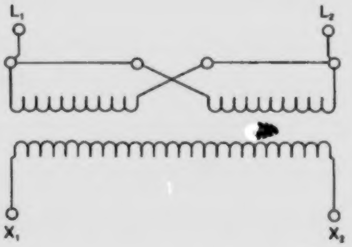
Written Test

Objective 5

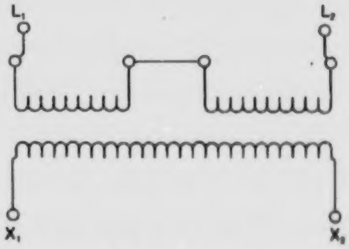
Match the voltage ratings with their typical control transformer schematics.

1. 480/120
2. 240/120
3. 240/24

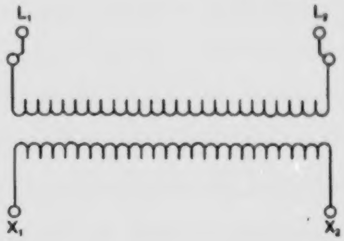
_____ a.



_____ b.



_____ c.



Objective 6

Describe the necessary changes that must be made to a starter when using a separate control circuit.

____

____

____

____

____

*Permission to duplicate this test is granted.

Answers to Written Test

Objective 1	a. 3 b. 5 c. 1 d. 4 e. 6 f. 2
Objective 2	a. To step control voltage down to safe levels b. To match control voltage with control components' operating voltage
Objective 3	a. Air conditioning and heating equipment b. Motor control centers c. Pump control panels
Objective 4	a. Control transformer b. Separate 120 volt control with circuit disconnect
Objective 5	a. 2 b. 1 c. 3
Objective 3	Remove wire between L_2 and the coil.

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* Assignment Sheets

1—Answer Questions Related to a Sequence Control Diagram . . . 199
2—Answer Questions Related to an Auxiliary Contact Interlocking Diagram 201

* Job Sheets

1—Wire Two Starters in Sequence 203
2—Wire Two Starters with Auxiliary Contact Interlocking 207

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Instructional Plan

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Teaching Suggestions

- Invite a local maintenance electrician to speak on the importance of sequencing and interlocking. Conduct a question and answer session after the talk.
- Visit a supply house to view the various types of interlocking devices. Have students write a brief description of what they learned.

Evaluation

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- Kissell, Thomas E. *Industrial Electronics: Applications for Programmable Controllers, Instrumentation and Process Control, and Electrical Machines and Motor Controls*, 2nd ed. Upper Saddle River, NJ: Prentice-Hall Inc., 2000.

Answers to Assignment Sheets

Assignment Sheet 1

Answer Questions Related to a Sequence Control Diagram

A. (1) Coil M_1, energizes.
   (2) Contact M_1, Rung 2 closes, sealing in coil M_1 and energizing Rung 3.
   (3) Contact M_1, Rung 5 opens, de-energizing red light.

B. If coil M_1 is not energized, nothing will happen. This is due to the fact that the three-wire control feeds from terminal 3 on starter M_1. If coil M_1 has been energized, coil M_2 will energize. Contact M_2 on rung 4 will close. Contact M_2 on rung 6 will open killing the red pilot light.

C. (1) Coil M_2 de-energizes.
   (2) Contact M_2, Rung 4 opens.
   (3) Contact M_2, Rung 6 closes, energizing red light.

D. (1) Rungs 1, 2, 3, and 4 de-energize.
   (2) Contact M_1, Rung 2 and contact M_2, Rung 4 open.
   (3) Contact M_1, Rung 5 and contact M_2, Rung 6 close and red lights energize.

E. No. Power will not flow to Rung 3 unless coil M_1 is energized.

Assignment Sheet 2

Answer Questions Related to an Auxiliary Contact Interlocking Diagram

A. Nothing happens because N/O contact M_1 is open.

B. Rungs 13, 14, 15, and 16. They are "off" indicators.

C. Yes, because N/O interlocking on Rung 10 is operated by M_1 and there is not N/C interlocking.

Written Test

Name ______________________________

Date ______________________ Score __________

Objective 1

Define the following terms related to sequence control.

a. Auxiliary contacts— ______________________________

b. Phase to phase— ______________________________

c. Down stream— ______________________________

d. Interlocking— ______________________________

Objective 2

State the purpose of sequence control.

____

Objective 3

List two advantages of sequence control.

a. ______________________________

b. ______________________________

Objective 4

List two uses of sequence control.

a. ______________________________

b. ______________________________

Written Test

Objective 5

State the purpose of auxiliary contact interlocking.

Objective 6

List two advantages of auxiliary contact interlocking.

a.

b.

Objective 7

List two uses of auxiliary contact interlocking.

a.

b.

***Permission to duplicate this test is granted.**

234

Answers to Written Test

Objective 1

a. Contacts of a switching device in addition to the main circuit contacts; auxiliary contacts operate with the movement of the main contacts; can be N/O or N/C
b. Unintentional contact of two or more electrical phases; results in a short circuit
c. Coming after; following other devices or events
d. Interrelating with other controllers; a device is connected in such a way that the operation of one part controls the operation of another

Objective 2

To assure that one motor is running before any other can operate

Objective 3

a. Assures proper order of start-up
b. Shuts down all "down-stream" motors when a starter fails due to overload

Objective 4

a. Main or subassembly line conveyors
b. Auxiliary equipment associated with machines

Objective 5

To prevent two machines or starters from conflicting with one another

Objective 6

a. Prevents motor starters from being energized when not desired
b. Allows another method of sequencing motor starters

Objective 7

a. Reversing starters
b. Machine tools

Unit Contents

Teacher Page

Teacher Components

Suggested Activities 12–3
Answers to Assignment Sheets 12–9
Written Test 12–11
Answers to Written Test 12–15

Student Page

Student Components

Learning Activities Sheet 12–3
Objective Sheet 12–5
Information Sheet 12–7

* Assignment Sheets

1—Convert Ladder Diagrams to Wring Diagrams 211
2—Determine the Number of Conductors Needed to Operate Jogging Controls 213

* Job Sheets

1—Wire a Job Through a Lock-Stop Push Button 215
2—Wire a Job Through a Two-Position Selector Switch 219
3—Wire a Job Through a Two-Circuit Push Button 223
4—Wire a Job Through a Control Relay 227

* Assignment Sheets and Job Sheets are located in Student Workbook 2.

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make copies of any teacher supplements that will be provided for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Have students complete the focus assignment to introduce topics presented in unit of instruction.

Suggested Activities

- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheets. Review with students the criteria for evaluation of these activities.
- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Visit a local industry and view jogging controls in use. Discuss in class what was learned during the visit.
- Visit a school machine shop and view jogging controls on lathes. Have students write a brief description of their observations.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the assignment sheets. Rate the student using the criteria listed on each assignment sheet. See Answers to Assignment Sheets for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.
- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

  Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

Sample A

4—**Skilled**—Can perform job with no additional training.
3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
1—**Unskilled**—Is familiar with process, but is unable to perform job.
0—**No exposure**—No information or practice provided during training program.

Sample B

Yes—Can perform job with no additional training.
No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Alerich, Walter N. *Electric Motor Control*, 4th Ed. Albany, NY: Delmar Publishers, Inc., 1988.
- Kaltwasser, Stan and Gary Flowers. *Commercial and Industrial Wiring*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.
- *National Electrical Code, 2002*. Quincy, MA: National Fire Protection Association, 2001.
- *National Electrical Code 1993*. Quincy, MA: National Fire Protection Association, 1992.
- *National Electrical Code 1999*. Quincy, MA: National Fire Protection Association, 1998.

Suggested Supplemental Resources

Print Media

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  Provides a detailed view of the most important changes in the 2002 NEC

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Answers to Assignment Sheets

Assignment Sheet 1

Convert Ladder Diagrams to Wiring Diagrams—Diagrams may vary, but all should contain the complete information depicted in the ladder diagram and be workable.

Assignment Sheet 2

Determine the Number of Conductors Needed to Operate Jogging Controls

A. Conduit 1—3 conductors; #10 AWG
Conduit 2—4 conductors; #14 AWG
Conduit 3—4 conductors; #14 AWG
Conduit 3—3 conductors; #10 AWG
Conduit 4—3 conductors; #10 AWG
Dual element fuse—30 amp
Heater—Answer dependent upon selection charts used

B. Conduit 1—3 conductors; #16 AWG
Conduit 2—3 conductors; #12 AWG
Dual element fuse—15 amp
Heater—Answer dependent upon selection charts used

Written Test

Name ______________________________

Date ______________________ Score __________

Objective 1

Define the term jogging.

____

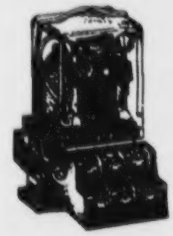
____

____

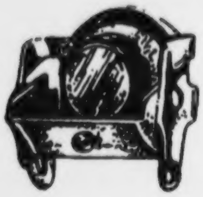
____

Objective 2

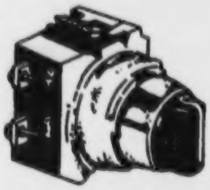
Identify the methods of jogging control shown below. Write your answers in the blanks provided.



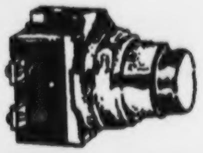
a. ____________



b. ____________



c. ____________



d. ____________

Written Test

Objective 3

Match the methods of jogging control with their correct advantages.

Note: There may be more than one correct answer.

1. Two position selector switch
2. Lock-stop push button
3. Two circuit push button
4. Control relay

_____ a. Extremely reliable; may be used on multiple starters

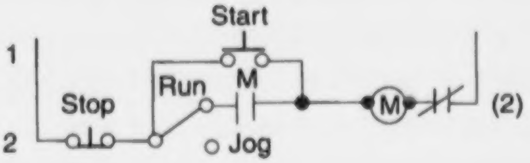
_____ b. Inexpensive; easy to install or retrofit; reliable

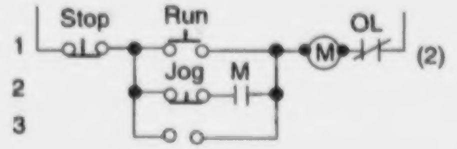
_____ c. Easy to operate; easy to install on initial wiring

Objective 4

Describe the sequence of operation of the three following ladder diagrams.

a .




Stop
Run
OL
1
2
3
Jog
M
M
(2)

b.

____

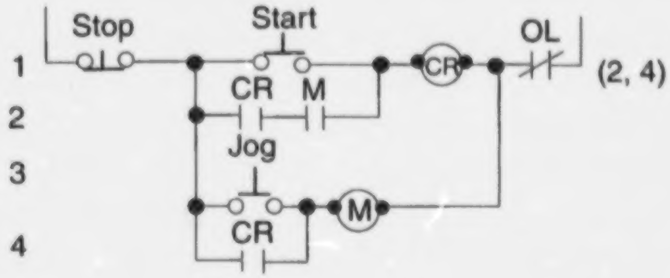
____

____

____

____

____


Stop
Start
OL
1
2
3
4
CR
CR
M
Jog
M
CR
(2, 4)

c.

____

____

____

____

____

____

*Permission to duplicate this test is granted.

Answers to Written Test

Objective 1

The quickly repeated closure of a circuit to start a motor from rest for the purpose of accomplishing small movements

Objective 2

a. Control relay
b. Lock-stop push button
c. Two-position selector switch
d. Two-circuit push button

Objective 3

a. 4
b. 1,2
c. 3

Objective 4

Description should include:

a. When switch is closed, it reacts as a normal three-wire control. When switch is open, seal in circuit is open.

b. When jog is pressed, seal in circuit is opened and coil is energized through N/O portion of two-position push button.

c. When start button is pressed, coil CR energizes, contact CR on Rung 2 closes, and contact CR on Rung 4 closes energizing coil M. When coil M energizes contact M, Rung 2 closes sealing in CR and M. When jog is pressed, coil M energizes, when jog is released coil M de-energizes.

Unit Contents

Teacher Components

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Suggested Activities 13–3

Answers to Assignment Sheets 13–9

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Student Components

Student Page

Learning Activities Sheet 13–3

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Information Sheet 13–9

* Assignment Sheets

- 1—Describe the Sequence of Operation of Ladder Diagrams 231
- 2—Determine the Number of Conductors Needed to Operate a Reversing Control 235

* Job Sheets

- 1—Wire a Reversing Starter with a Three-Position Selector Switch 237
- 2—Wire a Reversing Starter with One Control Station Using Auxiliary Contact and Mechanical Interlock 241
- 3—Wire a Reversing Starter with One Control Station Using Push Button Interlock and Auxiliary Contact Interlock 245
- 4—Wire a Reversing Starter with Two Control Stations 249
- 5—Wire Drum Switches 253
- 6—Wire a Reversing Starter with Jog in Both Directions 257

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Instructional Plan

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Teaching Suggestions

- Disassemble several reversing starters and show the class while describing how mechanical interlocking works.
- Arrange a tour of a supply house to view different brands and sizes of reversing starters. Conduct a class discussion on the similarities and differences students observed in the different brands.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
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Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

Sample A

4—**Skilled**—Can perform job with no additional training.
3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
1—**Unskilled**—Is familiar with process, but is unable to perform job.
0—**No exposure**—No information or practice provided during training program.

Sample B

Yes—Can perform job with no additional training.
No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

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Suggested Activities

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- Kissell, Thomas E. *Industrial Electronics: Applications for Programmable Controllers, Instrumentation and Process Control, and Electrical Machines and Motor Controls*, 2nd ed. Upper Saddle River, NJ: Prentice-Hall Inc., 2000.

Answers to Assignment Sheets

Assignment Sheet 1

Describe the Sequence of Operation of Ladder Diagrams—Exact answers may vary. Look for basic knowledge of the working systems.

Assignment Sheet 2

Determine the Number of Conductors Needed to Operate a Reversing Control

Conduit 1—1/2 inch (16); 3; #12

Conduit 2—3/4 inch (21); 8; #14

Conduit 3—1/2 inch (16); 5; #14

Conduit 4—3/4 inch (21); 3; #12 & 5, #14

Conduit 5—1/2 inch (16); 3; #12

Written Test

Name ______________________________

Date ______________________ Score__________

Objective 1

Match the terms related to reversing starters with their definitions. Write the correct numbers in the blanks.

1. Drum switch
2. Mechanical interlocking
3. Push-button interlocking
4. Racing
5. Reversing starters

_____ a. Means of locking out contactors through the use of mechanical devices such as cams or blocks

_____ b. A switch having electrical connecting parts in the form of fingers held by spring pressure against contact segments or the surface of a rotating cylinder

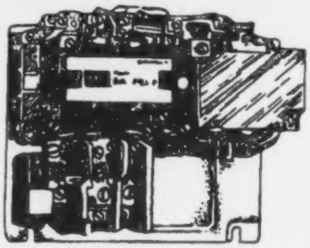
_____ c. Means of interlocking reversing starters through the use of two-circuit push buttons with normally open and normally closed contacts

_____ d. Starter consisting of two identical contactors and one overload relay assembly; used in reversal of polyphase motors

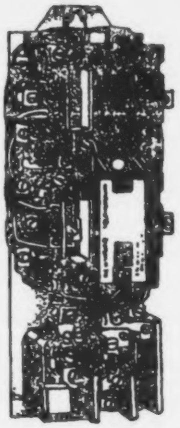
_____ e. Condition that occurs when both forward and reversing push buttons are operated simultaneously. Coils "race" to close

Objective 2

Identify the two types of reversing starter constructions shown below. Write your answers in the blanks provided.



a. ____________________



b. ____________________

Written Test

Objective 3

List three types of interlocking methods for reversing starters.

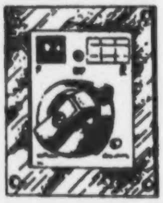
a. ______________________________

b. ______________________________

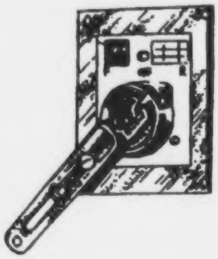
c. ______________________________

Objective 4

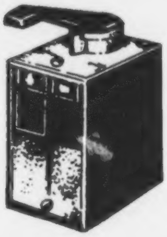
Identify the three types of drum switches shown below. Write your answers in the blanks provided.



a. ____________________



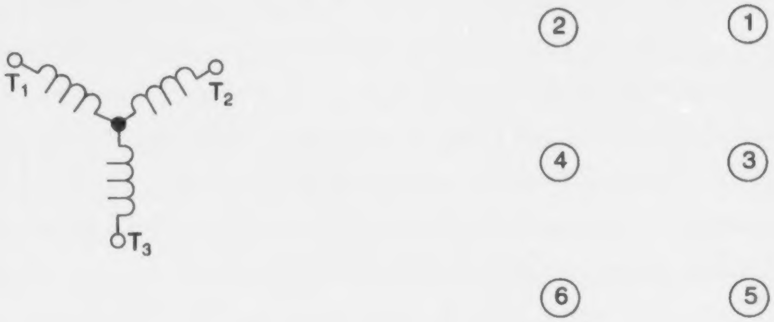
b. ____________________



c. ____________________

Objective 5

Complete the following drum switch diagram.



*Permission to duplicate this test is granted.

Answers to Written Test

Objective 1

a. 2
b. 1
c. 3
d. 5
e. 4

Objective 2

a. Horizontal construction
b. Vertical construction

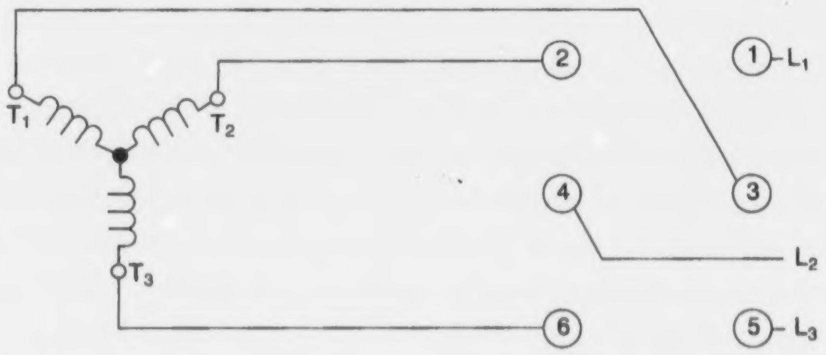
Objective 3

a. Push-button interlocking
b. Auxiliary contact interlocking
c. Mechanical interlocking

Objective 4

a. Flush mount knob operator
b. Flush mount adjustable operator
c. Surface mounting standard lever

Objective 5



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7—Build a Ground Fault Indicator Circuit 277

* Job Sheets are located in Student Workbook 2.

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make copies of any teacher supplements that will be provided for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

  TM 1—Typical Control Relay (Objective 2)
  TM 2—Latching Relay (Objective 4)

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Have students complete the focus assignment to introduce topics presented in unit of instruction.

Suggested Activities

- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheets. Review with students the criteria for evaluation of these activities.
- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Invite a maintenance electrician to speak to the class about special controls.
- Visit a local industry to view relays in use. Encourage students to ask questions and participate in a discussion of their observations after the visit.
- Visit a supply house and view various relays or have examples to demonstrate in class.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the assignment sheets. Rate the student using the criteria listed on each assignment sheet. See Answers to Assignment Sheets for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.
- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

Sample A

4—**Skilled**—Can perform job with no additional training.
3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
1—**Unskilled**—Is familiar with process, but is unable to perform job.
0—**No exposure**—No information or practice provided during training program.

Sample B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Alerich, Walter N. *Electric Motor Control*, 4th Ed. Albany, NY: Delmar Publishers, Inc., 1988.
- Kaltwasser, Stan and Gary Flowers. *Commercial and Industrial Wiring*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.
- *National Electrical Code, 2002*. Quincy, MA: National Fire Protection Association, 2001.
- *National Electrical Code 1993*. Quincy, MA: National Fire Protection Association, 1992.
- Rexford, Kenneth B. *Electrical Control for Machines*, 3rd Ed. Albany, NY: Delmar Publishers, 1987.
- *National Electrical Code 1999*. Quincy, MA: National Fire Protection Association, 1998.

Suggested Activities

Suggested Supplemental Resources

Print Media

- *2002 NEC Analysis of Changes*. Quincy, MA: National Fire Protection Association, 2001.

  Provides a detailed view of the most important changes in the 2002 NEC

- *NEC 2002 Handbook*. Quincy, MA: National Fire Protection Association, 2001.

  Contains complete Code text plus commentary, photos, and full-color graphics

  The publication(s) listed above can be ordered from:

  National Fire Protection Association
  1 Batterymarch Park
  Quincy, MA 02269-9101
  1-800-344-3555
  www.nfpa.org

- Carpenter, David. *Electrician's Technical Reference: Motor Controls*. Delmar Publishers, Inc. 2000.

- Dunning, Gary. *Introduction to Programmable Logic Controllers*, 2nd ed. Delmar Publishers, Inc. 2002.

- Early, Mark W., et al. *Illustrated Changes in the National Electrical Code*. Delmar Publishers, Inc. 2002.

  Provides a detailed view of the most important changes in the 2002 NEC

- Herman, Stephen L. *Electrician's Technical Reference: Industrial Electronics*. Delmar Publishers, Inc. 1999.

- Miller, Chris. *Illustrated Guide to the National Electrical Code*, 2nd ed. Delmar Publishers, Inc. 2002.

  Conveniently groups Code requirements according to type of occupancy, and contains 600 illustrations

- Mullin, Ray and Robert Smith. *Electrical Wiring Commercial*, 11th ed. Delmar Publishers, Inc. 2002.

- O'Riley, Ronald. *Electrical Grounding*, 6th ed. Delmar Publishers, Inc. 2002.

- Smith, Robert and Stephen Herman. *Electrical Wiring Industrial,* 11th ed. Delmar Publishers, Inc. 2002.
- Surbrook, Truman and Jonathan Althouse. *Interpreting the National Electrical Code,* 6th ed. Delmar Publishers, Inc. 2002.

  Offer practical examples to illustrate how articles in the Code are applied

- Titus, Patricia A., et al. *Illustrated Dictionary for Electrical Workers,* 2nd ed. Delmar Publishers, Inc. 2002.

  The publication(s) listed above can be ordered from:

  Thompson Learning
  Attn: Order Fulfillment
  P.O. Box 6904
  Florence, KY 41022
  1-800-477-3692
  www.delmar.com

- Kissell, Thomas E. *Industrial Electronics: Applications for Programmable Controllers, Instrumentation and Process Control, and Electrical Machines and Motor Controls,* 2nd ed. Upper Saddle River, NJ: Prentice-Hall Inc., 2000.

Written Test

Name ______________________________

Date ______________________ Score __________

Objective 1

Match the terms related to special control cirucits with their definitions. Write the correct numbers in the blanks.

1. Accelerating contactors
2. Motor driven timing relay
3. Pneumatic timing relay
4. Solid state timing relay

_____ a. Relay whose timed contacts are operated through the action of a variable speed, extremely small motor

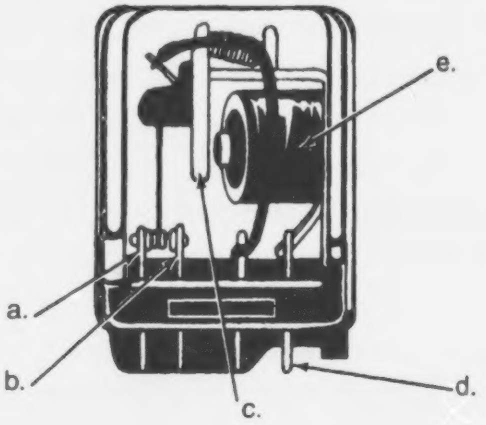
_____ b. Contactors or relays used in starting motors at low speed, then increasing to maximum speed in preset timed steps

_____ c. Relay whose timed contacts are operated by an electronic timer (microchip)

_____ d. Relay whose timed contacts are operated through the action of an air bellows and needle valve

Objective 2

Identify the parts of the control relay shown below. Write your answers in the blanks provided.



a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

Written Test

Objective 3

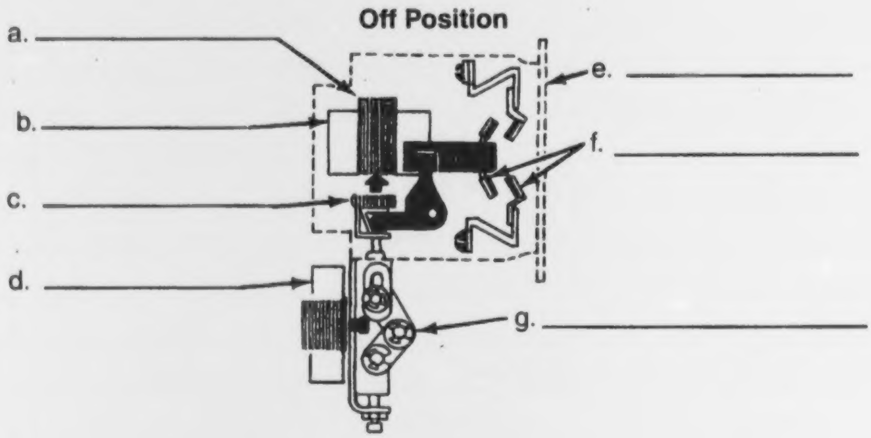
List two uses for control relays.

a. ______________________________

b. ______________________________

Objective 4

Identify the parts of the latching relay shown below.



Objective 5

Describe the reason for using latching relays or contactors.

____

____

____

____

Objective 6

List four types of timing relays.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

Objective 7

Complete the following statements regarding applications for timing relays by inserting the word(s) which best complte each application.

a. To control the ____________ contactors of motor starters.

b. To control a timed ________ ________ of industrial machinery.

c. To sequence on large loads for ________ ________ systems

Objective 8 Describe how a ground fault indicator works.

Objective 9 Describe the use of an alarm silencing circuit.

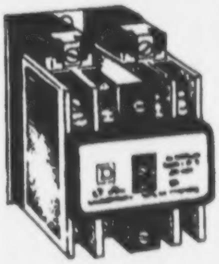
*Permission to duplicate this test is granted.

Answers to Written Test

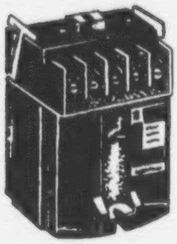
Objective 1	a. 2 c. 4 b. 1 d. 3
Objective 2	a. Normally closed contact b. Normally open contact c. Armature d. Coil terminals e. Coil
Objective 3	a. Control of fluid or pneumatic power valves b. Control of multiple circuits
Objective 4	a. Magnet b. Latch coil c. Armature d. Unlatch coil e. Baseplate f. Contacts g. Latch mechanism
Objective 5	To maintain contacts in their operated position during power off periods
Objective 6	a. Pneumatic timing relay b. Solid state timing relay c. Motor driven timing relay d. Timers
Objective 7	a. Accelerating b. Sequential start-up c. Energy management
Objective 8	When system has no grounds, both lights will glow at half brilliance. If a ground occurs, the light on the side without the ground will glow at full brilliance.
Objective 9	Alarms are used in industry to warn operators or other personnel of dangerous conditions. In an alarm condition an audible and visual signal are activated. The audible signal may be silenced, but the visual signal will remain on until the condition is cleared.

Teacher Supplement 1—Types of Control Relays

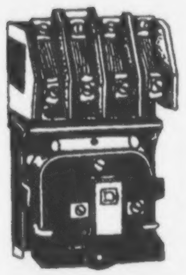
Industrial Control Relays



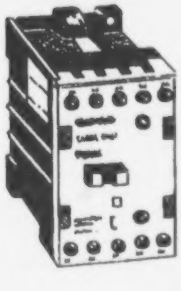
Type X



Type G

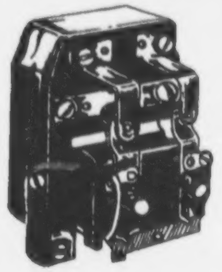


Type H

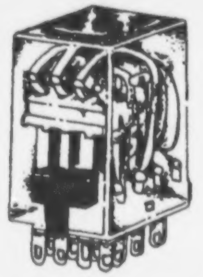


Type PH

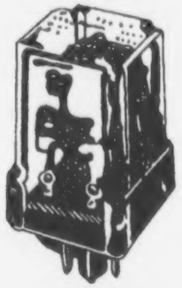
General Purpose Control Relays



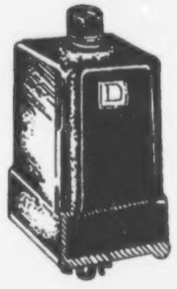
Type C



Type R



Type K

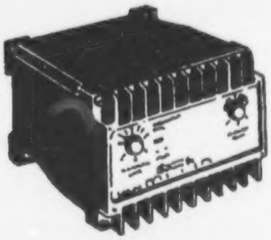


Type JCK

Teacher Supplement 1

Specialty Relays

Type DSC/DCS
Speed Control Relay



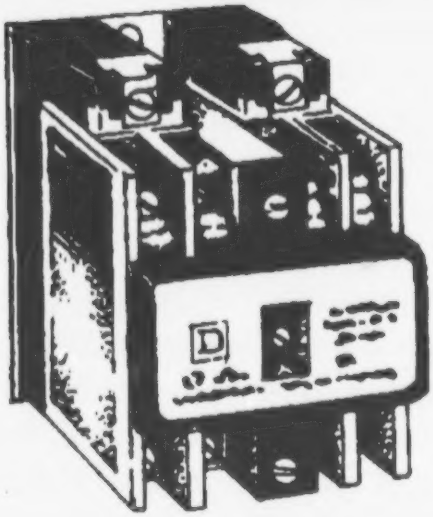
Type UBS
Undervoltage
Control Relay

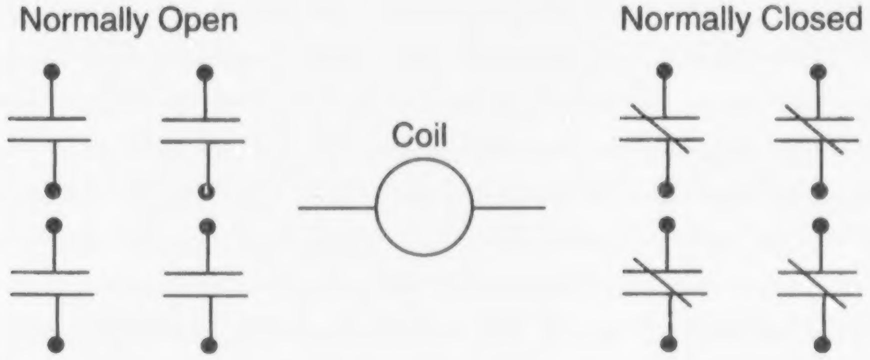
Courtesy of Square D Company.

Intrinsically Safe Relay

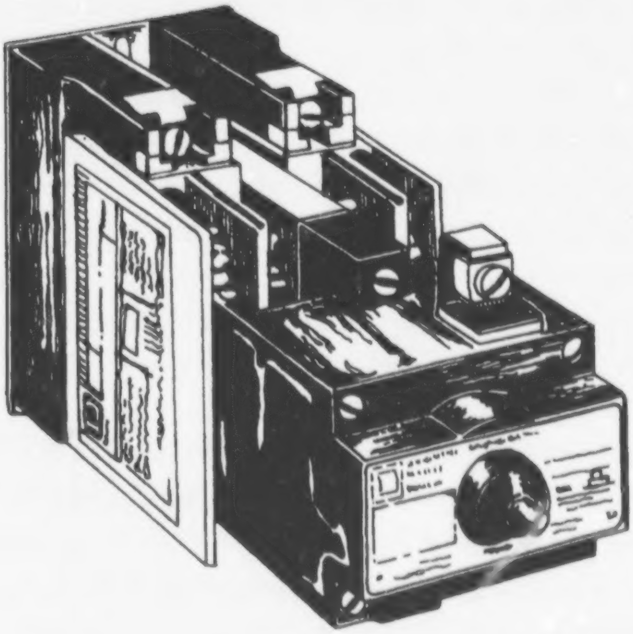
Barrier Relay

Typical Control Relay

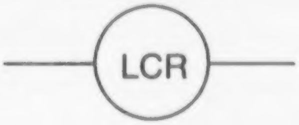



Normally Open
Coil
Normally Closed

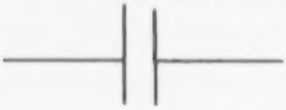
Latching Relay



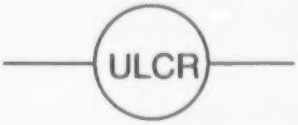
Latch Coil



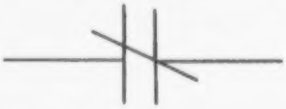
Normally Open Contact



Unlatch Coil



Normally Closed Contact



Courtesy of Square D Company.

Unit 15 Programmable Logic Controllers

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Teacher Components

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Teacher Supplement

- 1—PC Glossary 15–21

Transparency Master

- 1—Application of Programmable Logic Controllers 15–27

Student Components

Student Page

Learning Activities Sheet 15–3

Objective Sheet 15–5

Information Sheet 15–7

* Assignment Sheets

- 1—Match I/O Devices With Their Functions 279
- 2—Convert Between Numbering Systems 281

* Assignment Sheets are located in Student Workbook 2.

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make copies of any teacher supplements that will be provided for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

  TM 1—Application of Programmable Logic Controllers (Objective 2)

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.

Suggested Activities

- Have students complete the focus assignment to introduce topics presented in unit of instruction.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheets. Review with students the criteria for evaluation of these activities.
- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Visit an industry that uses programmable logic controllers. Encourage students to ask questions to clarify information that is given.
- Have PLC sales engineers demonstrate their product line. Discuss with the class any advantages or disadvantages they may have observed about the product.
- Show examples of input and output devices to class.
- Provide students with catalogs describing various types of programmable logic controllers and their specific features.

  Examples: Telemecanique, Square D
- Explain the different numbering systems and how they may apply to programmable logic controllers. Have students practice converting between number systems.
- Design lessons specific to the PLC used at your facility.

  Note: Due to the varied brands and types of programmable logic controllers used in the different training facilities, it is impossible to include any job sheets in this unit. It is suggested that each instructor develop a series of job sheets designed to instruct the student in the step by step use of the PLC manuals. Job sheets should begin with extremely simple programs and progress to scenario type jobs including all the previously learned steps.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.

- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.

- Evaluate the assignment sheets. Rate the student using the criteria listed on each assignment sheet. See Answers to Assignment Sheets for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.

- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

  Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

  Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

  Sample A

  4—**Skilled**—Can perform job with no additional training.
  3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
  2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
  1—**Unskilled**—Is familiar with process, but is unable to perform job.
  0—**No exposure**—No information or practice provided during training program.

  Sample B

  Yes—Can perform job with no additional training.
  No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.

- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.

- Reteach and retest as required.

Suggested Activities

Resources Used in Developing This Unit

Print Media

- Kaltwasser, Stan and Gary Flowers. *Commercial and Industrial Wiring.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1988.
- Rexford, Kenneth B. *Electrical Control for Machines*, 3rd Ed. Albany, NY: Delmar Publishers, 1987.
- *Tel-A-Train Workbook for PCs.* Chattanooga, TN: Tel-A-Train, Inc.

Suggested Supplemental Resources

Print Media

- *2002 NEC Analysis of Changes.* Quincy, MA: National Fire Protection Association, 2001.

  Provides a detailed view of the most important changes in the 2002 NEC
- *NEC 2002 Handbook.* Quincy, MA: National Fire Protection Association, 2001.

  Contains complete Code text plus commentary, photos, and full-color graphics

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  Quincy, MA 02269-9101
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  www.nfpa.org
- Carpenter, David. *Electrician's Technical Reference: Motor Controls.* Delmar Publishers, Inc. 2000.
- Dunning, Gary. *Introduction to Programmable Logic Controllers*, 2nd ed. Delmar Publishers, Inc. 2002.
- Early, Mark W., et al. *Illustrated Changes in the National Electrical Code.* Delmar Publishers, Inc. 2002.

  Provides a detailed view of the most important changes in the 2002 NEC
- Herman, Stephen L. *Electrician's Technical Reference: Industrial Electronics.* Delmar Publishers, Inc. 1999.
- Miller, Chris. *Illustrated Guide to the National Electrical Code,* 2nd ed. Delmar Publishers, Inc. 2002.

Conveniently groups Code requirements according to type of occupancy, and contains 600 illustrations

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Offer practical examples to illustrate how articles in the Code are applied

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P.O. Box 6904
Florence, KY 41022
1-800-477-3692
www.delmar.com

- Kissell, Thomas E. *Industrial Electronics: Applications for Programmable Controllers, Instrumentation and Process Control, and Electrical Machines and Motor Controls*, 2nd ed. Upper Saddle River, NJ: Prentice-Hall Inc., 2000.

Answers to Assignment Sheets

Assignment Sheet 1

Match I/O Devices With Their Functions

a. 1
b. 3
c. 4
d. 2

Assignment Sheet 2

Convert Between Numbering Systems

a. 0000-0111-1000
b. 0100-1001-0011
c. 0010-0000-0110
d. 1000-0101-0001
e. 516
f. 392
g. 287
h. A9F
i. 7DC
j. 65B

Written Test

Name ______________________________

Date ______________________ Score __________

Objective 1

Match the terms related to programmable logic controllers with their definitions. Write the correct numbers in the blanks.

1. Analog signal
2. Counter
3. Discrete
4. Fiber optics
5. Input
6. Logic
7. Networking
8. Output
9. Programmer
10. Programmable logic controller

_____ a. A logic element in a PLC user program that is used to simulate the operation of electromechanical counters

_____ b. A two-state reference in the user program that can be either on or off

_____ c. A system that contains digital switching functions, circuits, or devices

_____ d. A signal that provides the controller information about the system; can be discrete, numeric, or analog

_____ e. A device designed to allow inserting, monitoring, and editing a user program in the PLC

_____ f. A signal that varies proportionally with some aspect of the environment

_____ g. A signal coming from the controller to field devices; can be discrete, numeric, or analog

_____ h. A solid state control system that contains a user programmable memory for the storage of instructions to perform specific functions in an operation

_____ i. Transfer of discrete signals through glass fibers with light

_____ j. Tying in of multiple PLCs to communicate with each other in the performance of a process

Written Test

Objective 2

Select from the following list, programmable logic controller functions by placing an "X" in the blank preceding each correct function.

_____ a. The control of dangerous devices or devices in a dangerous environment

_____ b. Eliminating the need for retraining employees

_____ c. The facilitation of the change of a process at minimum expense and down time

_____ d. The performance of arithmetic operations that might be required for controlling certain operations

_____ e. Facilitation of 24-hour production of a product

_____ f. Fault locating, alarming, and regulation of devices that rarely need attention

Objective 3

List the four parts of a programmable logic controller.

a. ______________________________

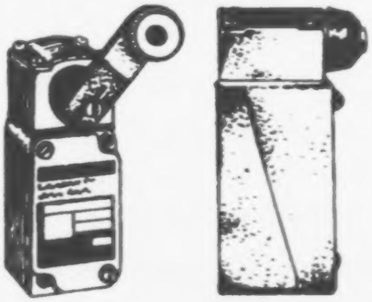
b. ______________________________

c. ______________________________

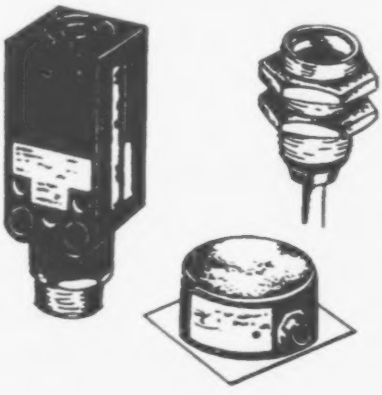
d. ______________________________

Objective 4

Identify the following input devices. Write your answers in the blanks provided.



a. ____________________



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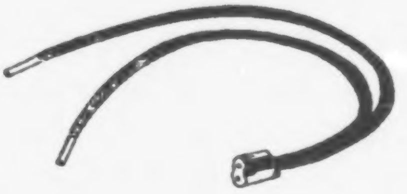
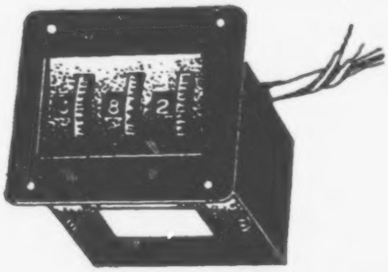
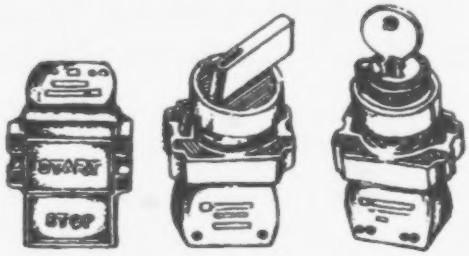


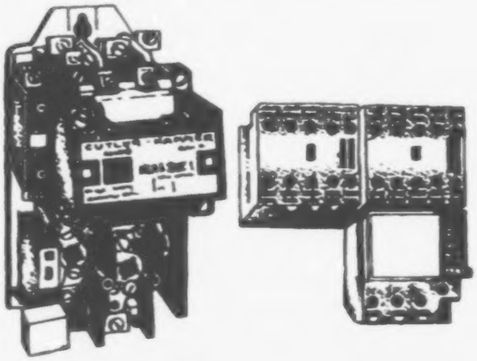


c. ______________________ d. ______________________



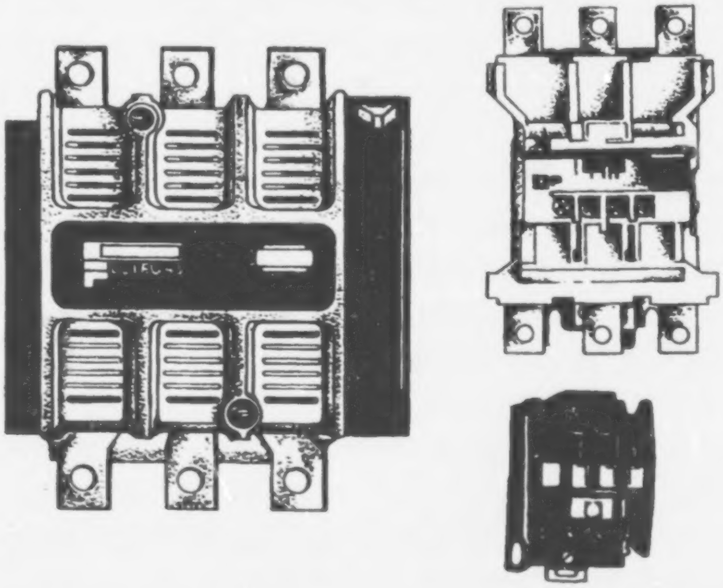
e. ______________________

Objective 5 Identify the following output devices. Write your answers in the blanks provided.

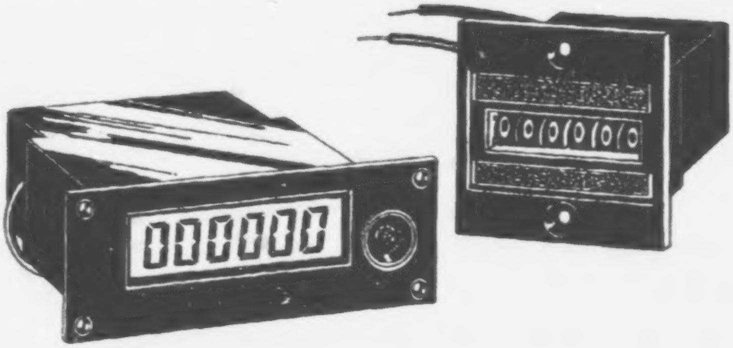

CUTLER-HAMMER

a. ______________________

Written Test



b. ____________________

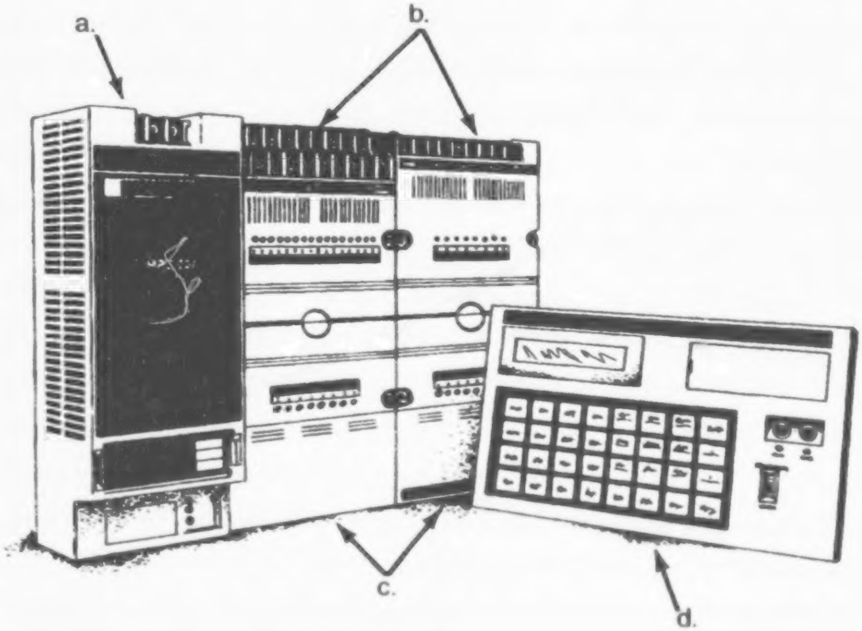


c. ____________________

Written Test

Objective 6

Identify the components of the programmable logic controller shown below. Write your answers in the blanks provided.



a. ______________________ b. ______________________

c. ______________________ d. ______________________

Objective 7

Complete statements concerning states of contacts by filling in the blanks with the correct answers.

a. A normally closed contact will be closed and passing power when it is ______________________.

b. A normally open contact will be open and not passing power when it is ______________________.

c. When ______________________, contacts change to the opposite state from their normal state.

Objective 8

Name three types of input/output modules.

a. ____

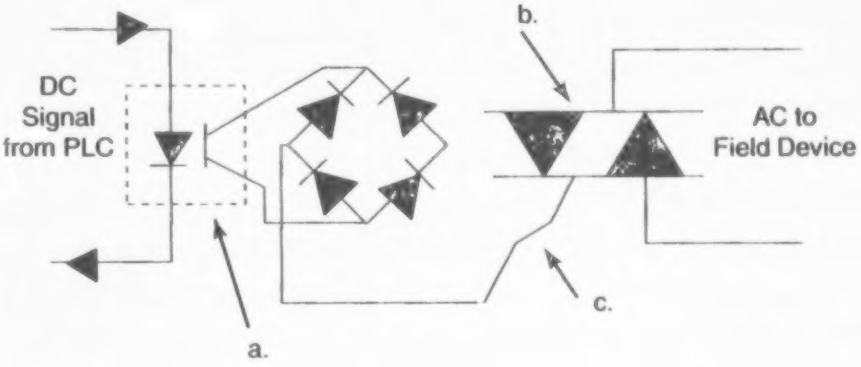
b. ____

c. ____

Written Test

Objective 9

Identify the parts of the optical coupler shown below. Write your answers in the blanks provided.

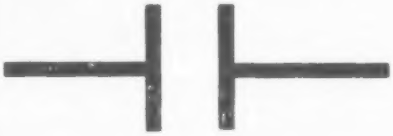

b.
DC Signal from PLC
AC to Field Device
c.
a.

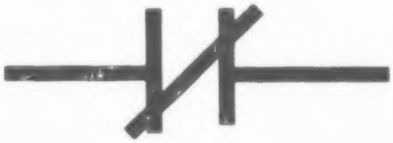
a. ______________________ b. ______________________

c. ______________________

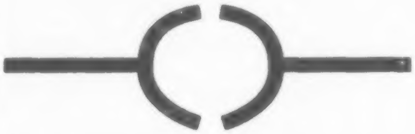
Objective 10

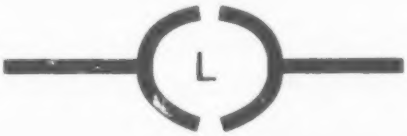
Identify the basic PLC ladder logic symbols shown below. Write your answers in the blanks provided.





a. ______________________ b. ______________________





c. ______________________ d. ______________________

Objective 11

Explain why a stop button is wired normally closed.

____

____

____

____

Objective 12

List the basic numbering systems used in programmable logic controllers.

a. ____

b. ____

c. ____

d. ____

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a. 2
b. 3
c. 6
d. 5
e. 9
f. 1
g. 8
h. 1
i. 4
j. 7

Objective 2

a, c, d, f

Objective 3

a. Input
b. Logic
c. Output

Objective 4

a. Limit switches
b. Proximity switches
c. Fiber optic probe
d. Thumbwheel
e. Push buttons

Objective 5

a. Motor starters
b. Contactors and relays
c. Counters

Objective 6

a. Controller
b. Input modules
c. Output modules
d. Programmer

Objective 7

a. Inactive
b. Inactive
c. Activated

Objective 8

a. Discrete
b. Numerical
c. Analog

Objective 9

a. Optical coupler
b. Triac
c. Gate

Objective 10

a. Normally open (examine on)
b. Normally closed (examine off)
c. Normal output coils
d. Latched output coils

Answers to Written Test

Objective 11

The N/C input is passing power to the I/O module. Sensing this voltage, the I/O sends an "on" signal to the controller.

Objective 12

a. Decimal
b. Binary
c. Octal
d. Hexidecimal

Teacher Supplement 1—PC Glossary

Note: The following glossary has been reprinted with permission of Tel-A-Train, Inc., Chattanoga, Tennessee.

A

Abort: a signal to terminate the current process.

Active Light: (see Status Light)

Address: a coded value used to identify a specific I/O Channel or Module, or the location of a Register in Memory.

Alphanumeric: series of characters, usually code, which contain a combination of letters, numerals, and/or special characters. e.g. B678$.

Analog Signal: a signal which varies proportionally with some aspect of the environment, e.g., the signal from a pressure transducer which varies with the amount of pressure being applied.

Analog I/O Module: an I/O Module which performs Analog-to-Digital (Input) or Digital-to-Analog (Output) conversions so that the Controller can communicate with Analog Field Devices.

And Circuit: a Series Circuit which allows power flow in the Logic only when all the conditions have been met.

ANSI: American National Standards Institute.

Application Program: (see User Program)

Arithmetic Function: a function which compares the contents of two or more registers arithmetically (+, −, x, ÷), (addition, subtraction, multiplication, division, etc.) and may take action as a result.

ASCII: standard alphanumeric characters established by the American Standards Institute.

B

Baud: the number of bits transmitted every second.

BCED (Binary-Coded Decimal): a system which uses four Binary Digits to represent each Decimal Digit (0-9) in a Decimal Number.

Binary: a numeric, base 2 system which uses values represented only by the numbers 0 and 1 (OFF/ON).

Bit: contraction for Binary Digit. A single digit whose value can be either 0 or 1. The smallest division of a PC word.

Bugs: software errors which cause unwanted behavior, or functional problems due to faulty hardware.

Bus: an electronic channel used to send or receive data.

Byte: a string of Binary Digits operated on as a unit. Unless otherwise specified, a byte normally contains eight bits.

C

Cascading Functions: connecting two or more Functions together to control one Output. Timers and Counters can be Cascaded together to produce results which cannot be achieved using one Counter or one Timer.

Channel: a group of I/O Modules that are separately connected to the Controller.

Checksum: an error detection technique which adds up the Bytes or Words of data and compares them.

Teacher Supplement 1

Chip: a very small section of semiconductor material, usually made of silicon, containing electronic circuits.

Clear: to return Memory to a nonprogrammed state.

CMOS Memory: an advanced form of semiconductor Memory which requires very little DC Power to retain its contents.

Code: programmed instructions.

Coil: an element in the logic program which will react in a discrete manner to the operations performed by the Programmable Controller. Its ON and OFF status can be output to the real world via an Output Module, and it may be used in other logical operations. Coils are normally turned OFF when power is removed from the Controller. (see Latched Coil)

Computer: a device which has a CPU, Memory, I/O Facilities, and a Power Supply. It accepts information, processes the data in a programmed manner, and gives you a result.

Computer Interface: circuitry which allows a Controller's Processor to communicate with a computer.

Contact: 1. the junction point on a ladder rung which when closed allows a complete path for power flow. 2. the points on a Relay which open or close when the Relay coil is Energized.

Counter: a logic element in a PC User Program which is used to simulate the operation of electromechanical Counters.

CPU (Central Processing Unit): the "brain" of the Controller System, consisting of the power supply, memory, and processor. All logic solving and decision making are performed here by the Processor. May also be called the MAINFRAME. Some-times the term "CPU" is used to refer only to the Processor.

CRT: a cabinet containing a Cathode Ray Tube to display programs such as Ladder Logic Diagrams. The CRT might also be used to display data lists and application reports.

Cursor: a visible movable pointer on a CRT or Programming Panel which indicates where an instruction is to be entered or an edit is to be made.

D

Diagnostic Program: a test program you can use to help isolate hardware problems in the PC and Application Equipment.

Digital: having discrete states. Digital Logic can have up to 16 states. However, most Digital Logic is Binary Logic with two states, ON and OFF.

Disable: the ability to disconnect a Coil or discrete Input from its normal control. Usually done prior to Forcing. (see Forcing)

Discrete Reference: a two-state reference in the User Program which can be either ON or OFF. A discrete reference can be an Input, Output, or Internal Logic Element.

Disk Drive: a device used to read and write data on a magnetic disk.

Diskette: thin magnetically sensitive material which is placed in a Disk Drive for the purpose of storing data and loading the memory contents of a computer.

Documentation: an orderly collection of data and diagrams explaining the hardware and software involved in a Control System.

Down Load: transferring the User Program from the Controller to some other device, usually a programming device.

Dump: recording the entire contents of User Memory onto a storage medium (e.g., magnetic tape, floppy disk, etc.)

E

EAROM: Electrically Alterable Read-Only Memory.

Edit: to deliberately modify the user program.

EEPROM: Electrically Erasable Programmable Read-Only Memory.

EIA: Electronic Industries Association, an agency which sets standards in electronics.

Element: the basic building block of the PC ladder logic diagram. An element might be a relay contact, a horizontal short, a vertical short, a fixed numeric value, register reference, coil, or higher function. These are sometimes called logic elements.

Enable: to reconnect a logic coil or discrete input after it has been disabled. The opposite of "Disable."

EPROM: Erasable Programmable Read-Only Memory. This type of ROM can be erased with ultraviolet light and then reprogrammed.

Executive (Memory): an operating system which processes the User Program.

F

FIFO Operation: data management which assures that the First In will be the First Out.

Force: the operation which can be done to change a reference's status. The reference can be changed from OFF to ON or ON to OFF. This allows you to energize or not energize an Output by means of the Programming Device to aid in troubleshooting.

H

Hard Copy: a printed copy of information from a computer, such as a Ladder Logic Program listing.

Hardware: the mechanical, electrical, and electronic devices which make up a complete Programmable Controller System.

Holding Register: a storage block of the memory which holds a value and can be accessed through its Address.

Hexidecimal: the base 16 Number System often used to present error codes to the User.

I

Image Table: a table in the Memory which contains the status of all Inputs, Coils, and Registers.

Input: a signal which provides the Controller information about the system. It can be discrete (push button, relay contacts, limit switches, etc.) or Numeric (thumbwheel, external solid-state device, etc.), or Analog.

Input Field Devices: devices which supply data to the PC.

Input Module: a device which connects the Controller with Input Devices. The Input Module contains the circuitry required to convert the incoming signals to voltages which can be used by the PC.

I/O: Input/Output, the Controller's connection to the field devices; includes both discrete and register signals.

Isolated I/O: designed to enable the connection of field devices powered from different sources to a single module; this type of I/O is electrically isolated from all other circuits in the Module.

Interface: circuitry which allows communication between the Processor and the Field.

L

Ladder Diagram: an industry standard for representing Control Logic along Rungs in a ladder arrangement and using relay equivalent symbology.

Ladder Listing: a hard copy listing of the User Logic Program.

Latched Coil: a type of Coil which will return to its last state after a power failure has been rectified. These Coils are unlike normal Coils which reset to OFF at Powerup. (see "Retentive" if your Controller allows this function.)

LCD (Liquid Crystal Display): a reflective visual readout which offers the advantage of extremely low power consumption.

LED: Light Emitting Diode.

Logic: a system which contains digital switching functions, circuits, or devices, as in Programmable Controllers.

Logic Diagram: a graphic representation of Logic Functions and conditions.

Logic Element: any one of the symbols or functions which can be used in a Ladder Logic Diagram.

M

Machine Language: a Program which has been written in Binary.

Mainframe: (see Processor)

Memory: storage area for Binary Data and Programs.

Memory Map: a diagram which shows where in the Controller's Memory various kinds of data are held.

Memory Protect: a hardware feature usually under keylock control which prevents a portion of the Memory from being altered by an external device.

Microprocessor: the control and processing section of a small Computer.

Microsecond: one millionth of a second.

Millisecond: one thousandth of a second.

Modem: a device which converts digital signals to analog signals suitable for transmission over a telephone line and vice-versa.

Move Function: the capability, in some PCs, which allows data to be transferred from a Register to a Table and from a Table to a Register.

Multiplexing: the ability to transfer a number of different data signals through a single channel.

N

Network: a group of logic elements which has been connected together to perform a single function. In some Controllers, it is a subdivision of the User Program.

Node: the point on a PC Ladder Rung where a logic element is entered into a Ladder Logic Diagram.

Noise: random unwanted electrical signals, usually generated outside the Controller, which can cause errors in a PC managed system.

Non-Volatile Memory: memory which does not lose its information when power is turned off.

Normally Open Contact (Examine On Contact): a Contact whose not active state is Open. It is examining for an ON Signal in order to go active and close.

Normally Closed Contact (Examine Off Contact): a Contact whose not active state is Closed. it is examining for an OFF Signal in order to pass power. If it finds a voltage ON signal at an input location, it goes Active, opens, and will not pass power.

O

Octal: the Base Eight Numbering System which is used by some PC Manufacturers for Addressing I/O terminals and Referencing Registers.

Off-Line Operation: equipment or devices which are operating, but not affecting the system.

On-Line Operation: operations where the PC is directly controlling a machine or process.

One-Shot: a discrete reference, usually a Logic Coil, which is energized for exactly one scan of the Controller's Logic.

Optical Coupler: a device which uses a light source and a detector to link two points and provide electrical isolation. Often found in I/O Modules.

OR Circuit: a Parallel Circuit which allows one or more alternate paths for power flow in the Logic.

Output Signal: a signal coming from the Controller to the Field Devices in an operation. It can be discrete, turning Field Devices OFF and ON. Or it can be Numeric, displaying values stored in Registers. Or it can be Analog, sending a proportional signal to a Field Device.

Output Field Devices: devices such as Solenoids, Motor Starts, and Readouts which receive signals from the PC.

Output Module: a device used to connect the PC with working devices in the field. It serves two primary functions: converting PC signals to usable output voltages and isolating the PC from power fluctuations in the Field.

P

Parity Check: an error test which counts the number of "1s" in a binary Digit and records whether it is odd or even.

Parallel Circuit: (see OR Circuit)

Peripheral Equipment: units which may communicate with a PC but are not part of it.

Port: an I/O connection point on a Controller or Peripheral Device.

Processor: the "brain" of the PC which performs all the decision-making in the Controller.

Programmable Controller (PC): a solid state Control System which contains a User Programmable Memory for the storage of instructions to perform specific functions in an Operation. A PC consists of a Central Processing Unit and an I/O Interface. It requires a Programming Device to enter a User Program into its Memory.

Programming Device: a device designed to allow inserting, monitoring, and editing a User Program in the PC.

PROM (Programmable Read-Only Memory): a retentive Memory used to store data.

R

RAM (Random Access Memory): a portion of the Memory which is used to store the Information necessary to control a particular operation. This information can be accessed at Random by the processor when it is needed.

Reference Numbers: numbers which identify Elements of the Relay Ladder Logic. These Elements can be either Discrete or Numeric.

Register: a piece of the Controller's Memory which has been set aside for the storage of Numeric Values. The contents of these Registers can be referenced and used by the PC during its operation.

Register Module: sometimes called Numeric and Analog Modules, these I/O Modules allow numerical data to pass between the PC and the Field Devices.

Relay: an electromechanical device which controls other devices in an electrical system.

Relay Element: a Logic Symbol used to simulate the effect of an electromechanical Relay in a User Program.

Retentive Elements: on certain Controllers, these Logic Elements will retain their state or value under specified conditions, e.g., a Retentive Latched Coil may remain latched when power is removed from the PC; a Retentive Timer will retain its Accumulated Time during a power outage provided battery power is supplied.

ROM (Read Only Memory): a portion of Memory which is usually programmed by the Manufacturer and contains basic instructions for the PC.

Rung: a single horizontal line in the Ladder Logic which may contain User Program Elements.

S

Scan: the cycle a PC performs several times each second, during which it reads the inputs, solves the User Program, and sets the outputs.

Scratch Pad Memory: a temporary portion of Memory where the PC stores the data it needs to perform calculations or control an operation. Often this area is used because it offers faster access time than the Main Memory.

Sequencer: a Logic Element which allows events to be programmed to follow a certain order under specified conditions.

Series Circuit: (see AND Circuit)

Skip Function: on certain Controllers, this function allows certain portions of a Program to be skipped when the Logic is being scanned.

Software: application and internal programs which are used to support the performance of the Controller.

Solid-State: circuitry using only integrated circuits, transistors, diodes, etc., and containing no electromechanical devices or vacuum tubes.

Status Light: an LED Indicator found on most I/O Modules which can be used as a maintenance aid. It usually lights to indicate that an Output Module is receiving valid data from the Processor, or that an Input Module is receiving a signal from a Field Device.

T

Table: a group of consecutive Memory Registers used to store numerical values.

Timer: a Logic Element which uses the PC's internal clock to time an event or sequence of events. (see Retentive if your Controller allows this function.)

Traffic Cop: a portion of Executive Memory which controls how input and output data are handled.

Transitional Contact: a Contact which will pass power for exactly one scan whenever the Coil or Discrete input to which it is referenced goes from OFF to ON or ON to OFF (depending upon the transitional type selected).

Triac: a semi-conductor device which acts as an electronic switch for AC loads.

Truth Table: a listing which shows the state of an Output under all the possible Input conditions.

U

Up-Load: transferring data to the PC from a device such as a Programmer.

User Memory: the area in memory where the Application, or User Program is stored.

User Program (Application Program): a set of Instructions written by the user and stored in the Memory. These instructions "tell" the Processor how to control a specific operation.

V

Volatile Memory: a type of Memory which will lose its information if power is removed from it.

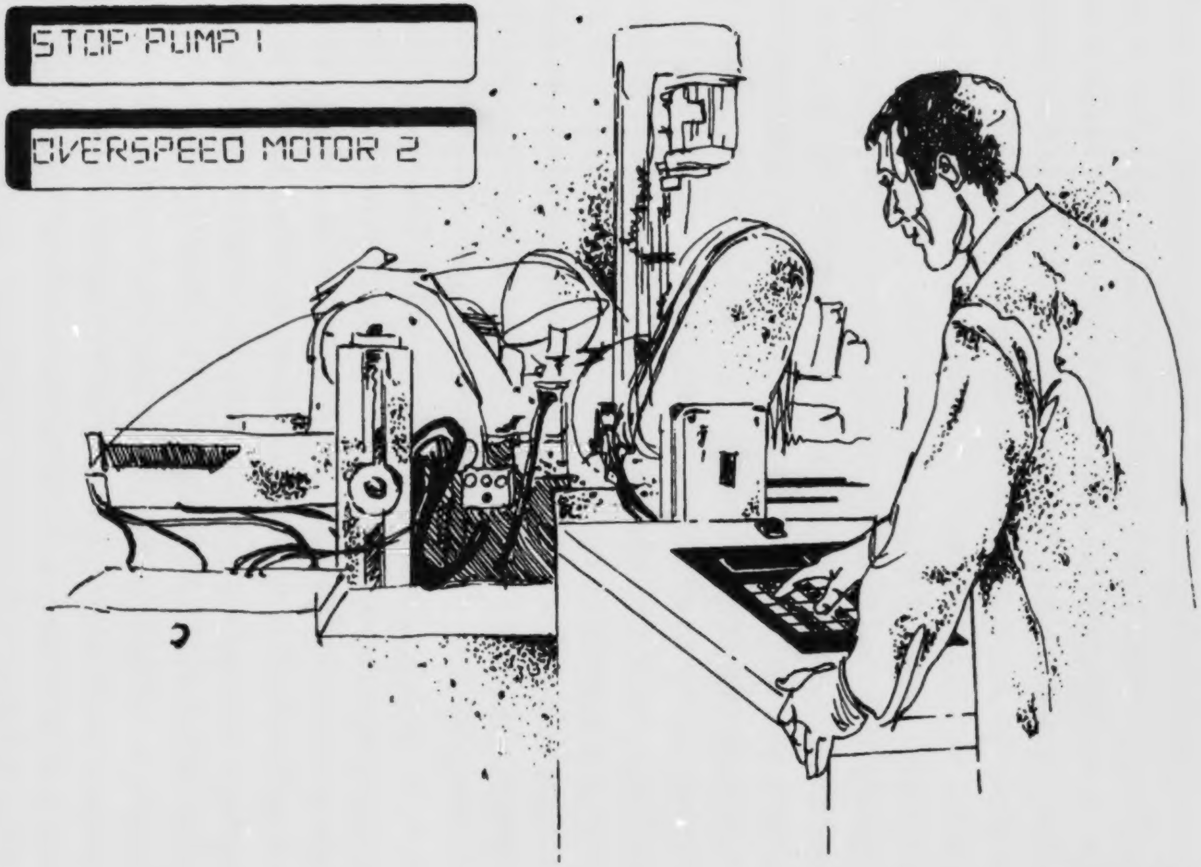
W

Watchdog Timer: a safety circuit which uses a Timer to check constantly for CPU failure. When the CPU is operating correctly, the Timer is periodically reset so it never Times Out. In the event of failure, the Timer Times Out and the entire system is shut down.

Word: a grouping of bits (usually 16) into a sequence which is treated as a unit.

Write: the act of putting data into a storage location.

Application of Programmable Logic Controllers


STOP PUMP 1
OVERSPEED MOTOR 2

Courtesy of Telemechanique.

Special Supplement
Suggestions to the Instructor

The following scenarios are designed to develop in the student the critical thinking skills necessary to make competent judgments based on available data or information. The problems provided in these scenarios will encompass most of the skills learned in the commercial and industrial wiring curriculum. Application of these problems should also develop skills in work ethics and give the student a basic understanding of the economics of the electrical industry. The student should also show marked improvement in communication skills, trade related mathematics, and team participation.

1. Two-wire control applications
2. Timed operation applications
3. Reversing applications
4. Oil field applications
5. Reversing alternative applications
6. Limitation of movement applications
7. Back spin protection applications
8. Hazardous mixing applications
9. Sequential starting applications
10. Sequential shutdown applications

In order to implement the above scenarios, the instructor should provide:

1. Electrical labor units manual
2. Electrical supply catalogs
3. Pricing books
4. Overhead and markup multipliers (based on local prices)
5. Varied motor control components

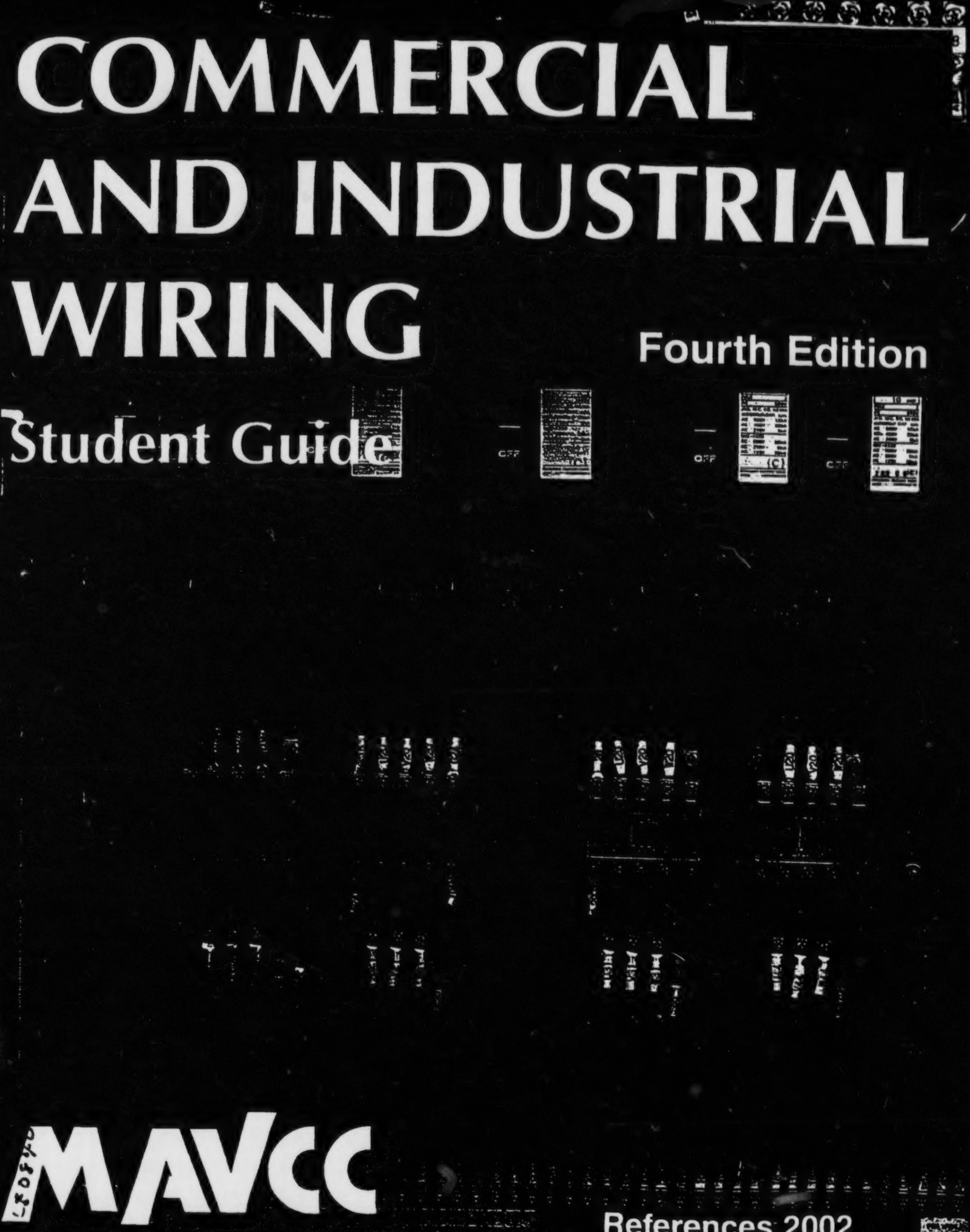
It is also suggested that the instructor review the scenarios and construct work stations for each problem. The work stations should have all starters, motors, and raceways installed. The student should be required to determine appropriate control devices as well as conductor size and overcurrent and overload protection. Many of the problems require a bid or price figure. Assist each student with the basics of pricing, overhead, and markup.

Suggestions to the Instructor

Each scenario problem will require a technical report. A detailed explanation of the sequence of operation of the circuit should be included. It should be referenced to the ladder diagram. Any additional pertinent information should also be included, eg, why a particular NEMA type of enclosure is necessary.

The problems will increase in difficulty as the student progresses through the supplement. The student should be encouraged to perform any necessary research on his/her own. Your role should change from instructor to technical consultant/evaluator.

No answer sheets have been provided for these scenarios due to the varied methods of problem solving.



COMMERCIAL AND INDUSTRIAL WIRING

Fourth Edition

Student Guide

MAVCC

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Commercial and Industrial Wiring

Fourth Edition

Student Guide

Written by

Stan Kaltwasser
Gary Flowers

Revised by

Dan Ipock

Project coordinated by

Glenn Fleming

Developed by

Multistate Academic and Vocational Curriculum Consortium, Inc.
1500 West Seventh Avenue
Stillwater, Oklahoma 74074-4364

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Oklahoma Department of Career and Technology Education
Stillwater, OK 74074-4364

For more information, contact the
Multistate Academic and Vocational Curriculum Consortium
1500 West Seventh Avenue
Stillwater, OK 74074-4364

E-mail: mavcc@mavcc.com
Internet: http://www.mavcc.org
Phone: (800)654-3988 or (405)743-5578

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Unit 1

Blueprint Reading and Load Calculations

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* Focus Assignment

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3—Compute Lighting Loads 17
4—Determine Maximum Numbers of Conductors in Conduit 19
5—Determine Wire Sizes to Prevent Excessive Voltage Drop 21

* Focus Assignment and Assignment Sheets are located in Student Workbook 1.

Prerequisites:
None

Learning Activities Sheet

Student Name ____________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Do** Focus Assignment, "Select Participants and Describe Their Functions at a Construction Site."

☐ 4. **Study** Information Sheet, Objectives 1 through 8 and 14.

☐ 5. **Do** Assignment Sheet 1, "Construct an Electrical Blueprint."

☐ 6. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 7. If the evaluation is not satisfactory, repeat Steps 4 and 5.

☐ 7. **Study** Information Sheet, Objectives 9 through 12.

☐ 8. **Do** Assignment Sheet 2, "Perform Load Calculations and Determine Overcurrent Protection and Conductor Size."

☐ 9. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 10. If the evaluation is not satisfactory, repeat Steps 7 and 8.

☐ 10. **Do** Assignment Sheet 3, "Compute Lighting Loads."

☐ 11. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 12. If the evaluation is not satisfactory, repeat Steps 7 and 10.

☐ 12. **Do** Assignment Sheet 4, "Determine Maximum Numbers of conductors in Conduit."

☐ 13. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 14. If the evaluation is not satisfactory, repeat Steps 7 and 12.

☐ 14. **Study** Information Sheet, Objective 13.

☐ 15. **Do** Assignment Sheet 5, "Determine Wire Sizes to Prevent Excessive Voltage Drop."

☐ 16. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 17. If the evaluation is not satisfactory, repeat Steps 14 and 15.

☐ 17. **Check** With instructor for any additional assignments to be completed.

☐ 18. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 19. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Objective Sheet

Unit Objective

After completing this unit, the student should be able to identify blueprint symbols, and compute load calculations and voltage drop. The student should demonstrate these competencies by completing the focus assignment, and assignment sheets, and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to blueprint reading and load calculations with their definitions.
2. Identify mechanical symbols.
3. Identify plumbing symbols.
4. Identify structural symbols.
5. Identify architectural symbols.
6. Identify electrical symbols.
7. Identify panel, circuit, and other electrical symbols.
8. Match types of blueprint lines with their pictures and descriptions.
9. List typical electrical specifications.
10. Complete statements concerning minimum requirements for electrical devices.
11. Determine motor-circuit wire sizes by using the *NEC.*
12. Select true statements concerning load calculations.
13. Select true statements concerning voltage drop.
14. Match types of blueprints with their correct descriptions.
15. Select participants and describe their functions at a construction site. (Focus Assignment)
16. Construct an electrical blueprint. (Assignment Sheet 1)
17. Perform load calculations and determine overcurrent protection and conductor size. (Assignment Sheet 2)
18. Compute lighting loads. (Assignment Sheet 3)
19. Determine maximum numbers of conductors in conduit. (Assignment Sheet 4)
20. Determine wire sizes to prevent excessive voltage drop. (Assignment Sheet 5)

Information Sheet

Objective 1

Terms and definitions

a. **Blueprint**—Copy of the original detailed drawings of a structure

b. **Blueprint lines**—Set of conventional symbols to depict an object

c. **Branch circuit**—The circuit that extends from the last overcurrent protection device to the outlets

d. **Demand factor**—The ratio of the maximum demand of a system or part of a system, to the total connected load of a system or the part of the system under consideration

e. **Feeder circuit**—All circuit conductors between the service equipment of the source of a separately derived system and final branch circuit overcurrent device

f. **Specifications**—A detailed set of written instructions that explains the drawing

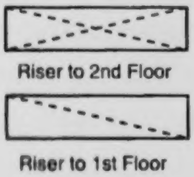
g. **Symbol**—An arbitrary sign that has been standardized and is used to represent an object, quantity, or method

h. **Voltage drop**—A reduction in available voltage at the end of a circuit

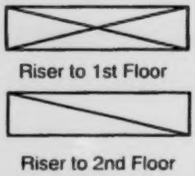
Objective 2

Mechanical symbols

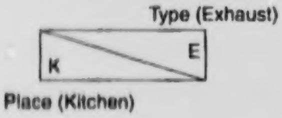
a. Duct section, exhaust return



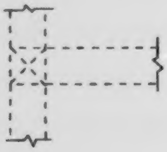
b. Duct section, supply



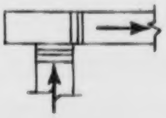
c. Duct section notation



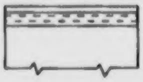
d. Duct connection below joist



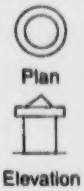
e. Fan flexible connection



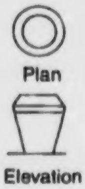
f. Louver 8 screen air intake



g. Rainproof ventilator


Plan
Elevation

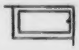
h. Standard ventilator


Plan
Elevation

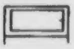
Objective 3

Plumbing symbols

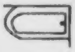
a. Corner bath



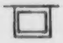
b. Recessed bath



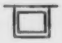
c. Roll rim bath



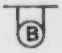
d. Sitz bath



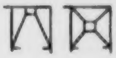
e. Foot bath



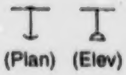
f. Bidet



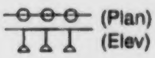
g. Shower stall



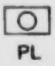
h. Shower head



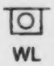
i. Overhead gang shower



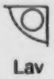
j. Pedestal lavatory



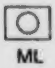
k. Wall lavatory



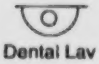
l. Corner lavatory



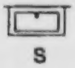
m. Manicure/medical lavatory



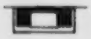
n. Dental lavatory



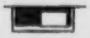
o. Plain kitchen sink



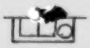
p. Kitchen sink, right and left drain board



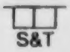
q. Kitchen sink, left hand drain board



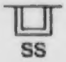
r. Combination sink and dishwasher



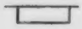
s. Combination sink and laundry tray



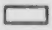
t. Service sink



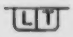
u. Wash sink (wall type)



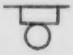
v. Wash sink



w. Laundry tray



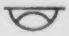
x. Water closet (low tank)



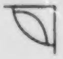
y. Water closet (no tank)

z. Urinal (pedestal type)

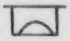
aa. Urinal (wall type)



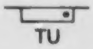
bb. Urinal (corner type)



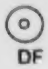
cc. Urinal (stall type)



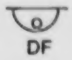
dd. Urinal (trough type)



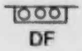
ee. Drinking fountain (pedestal type)



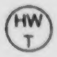
ff. Drinking fountain (wall type)



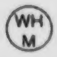
gg. Drinking fountain (trough type)



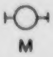
hh. Hot water tank



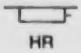
ii. Water heater



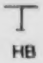
jj. Meter



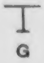
kk. Hose rack



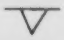
ll. Hose bibb



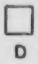
mm. Gas outlet



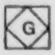
nn. Vacuum outlet



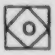
oo. Drain



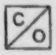
pp. Grease separator



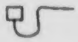
qq. Oil separator



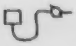
rr. Cleanout



ss. Garage drain



tt. Floor drain with backwater valve

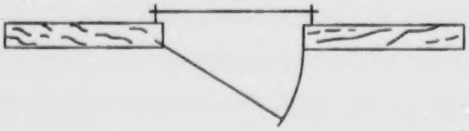


uu. Roof sump

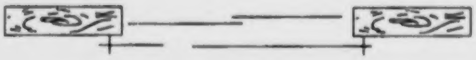
Objective 4

Structural symbols

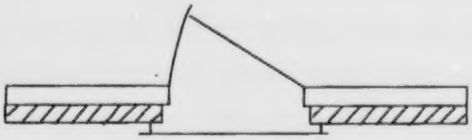
a. Plan view of exterior door in wood frame wall



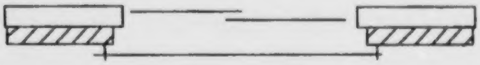
b. Plan view of exterior sliding door in wood frame wall



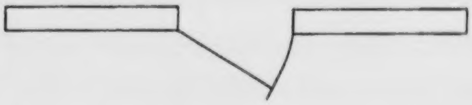
c. Plan view of exterior door in masonry veneer wall



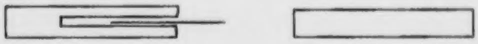
d. Plan view of exterior sliding door in masonry veneer wall



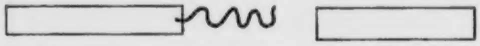
e. Plan view of interior hinged door



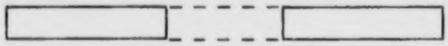
f. Plan view of interior pocket door



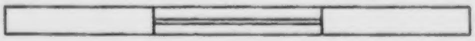
g. Plan view of folding door



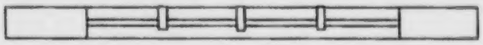
h. Plan view of plastered arch doorway



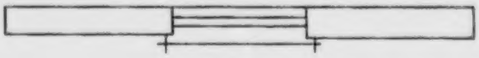
i. Plan view of single window in frame wall



j. Plan view of multiple windows in frame wall



k. Plan view of double hung window in frame wall



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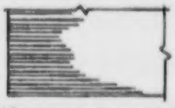
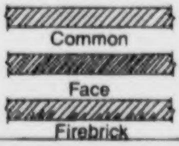
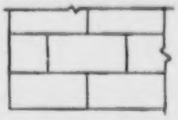
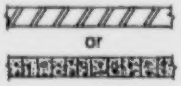
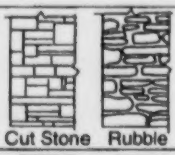
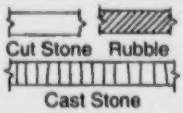
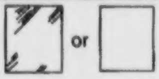
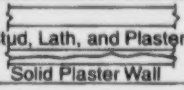
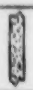
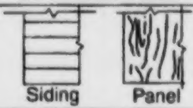
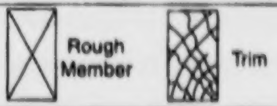
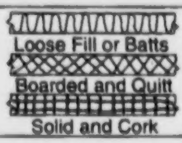
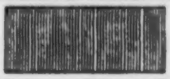
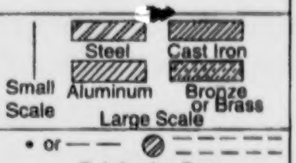
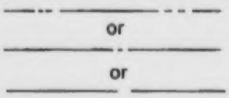
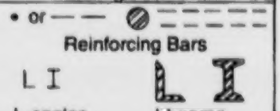
Objective 5 | Architectural symbols

	ELEVATION	PLAN	SECTION
Brick	 (Common, face, etc.)	 Common Face Firebrick	Same as plan view
Concrete Block		 or	
Stone	 Cut Stone Rubble	 Cut Stone Rubble Cast Stone (Concrete)	
Glass	 or	———	
Plaster		 Stud, Lath, and Plaster Solid Plaster Wall	
Wood	 Siding Panel	Floor areas are left blank, note indicates kind of wood used	 Rough Member Trim
Insulation		 Loose Fill or Batts Boarded and Quilt Solid and Cork	Same as plan view
Sheet Metal Flashing		Occassionally indicated by note	———
Metals Other than Flashing	Indicated by note or drawn to scale	Same as elevation	 Small Scale Steel Cast Iron Aluminum Bronze or Brass Large Scale
Structural Steel	Indicated by note or drawn to scale	 or or	 • or — — Reinforcing Bars L-angles Small Scale I-beams Large Scale

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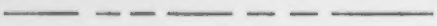
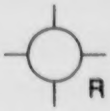
Objective 6

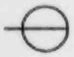
Electrical symbols

a.	Single pole switch	S
b.	Three-way switch	S_3
c.	Four-way switch	S_4
d.	Automatic door switch	S_D
e.	Key operated switch	S_K
f.	Switch with pilot light	S_p
g.	Weatherproof switch	S_{wp}
h.	Fused switch	S_f
i.	Double pole switch	S_2
j.	Switch for low voltage system	$\underline{S}$
k.	Circuit breaker	S_{cb}
l.	Remote control switch	S_{rc}
m.	Low voltage wire	
n.	Low voltage master switch	M_S

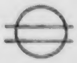
o. Relay equipped lighting outlet



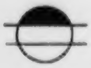
p. Single receptacle outlet



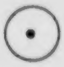
q. Duplex receptacle outlet



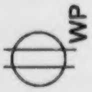
r. Split wired receptacle outlet



s. Floor receptacle outlet

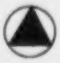


t. Weatherproof duplex outlet

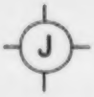


u. Special circuit

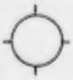
Note: This must be explained in the symbol key.



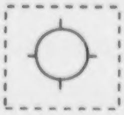
v. Junction box



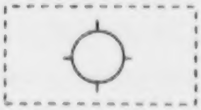
w. Lighting outlet



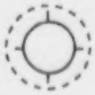
x. Square recessed light (size varies)



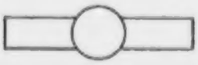
y. Rectangular recessed light (size varies)



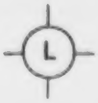
z. Round recessed light (size varies)



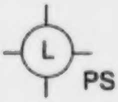
aa. Fluorescent light



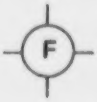
bb. Lampholder



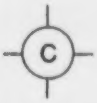
cc. Lampholder with pull switch



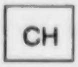
dd. Fan outlet



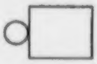
ee. Clock outlet



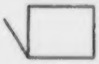
ff. Chime



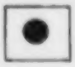
gg. Bell



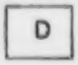
hh. Buzzer



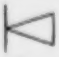
ii. Push button



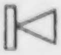
jj. Electric door opener



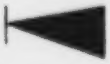
kk. Interconnecting telephone



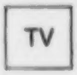
ll. Telephone switchboard



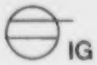
mm. Outside telephone



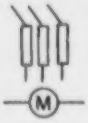
nn. Television outlet



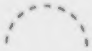
oo. Isolated ground receptacle



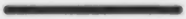
pp. Combination starter



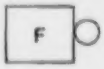
qq. Switch leg indicator



rr. Baseboard heat

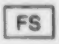


ss. Fire alarm bell



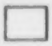
tt. Fire alarm station

uu. Automatic fire alarm device

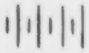


vv. Horn

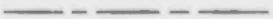
ww. Interconnection box



xx. Battery



yy. Auxiliary system circuits

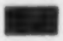


Objective 7

Panel, circuit, and other electrical symbols

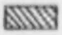
a. Lighting panel

Lighting panel is one having more then 10% of its over-current devices protecting lighting branch circuits, *NEC* Art 408.14(A).

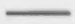


b. Power panel

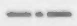
Power panel is one having 10% or fewer of its over-current devices protecting lighting and appliance branch circuits, *NEC* Art 408.14(B).



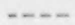
c. Branch circuit, concealed in ceiling or wall



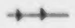
d. Branch circuit, concealed in floor



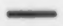
e. Branch circuit, exposed



f. Home run to panel board

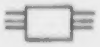


g. Feeder



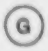
Note: Use heavy line and designate by the number corresponding to the listing in the feeder schedule

h. Under floor duct and junction box (triple system)

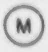


Note: For double or single systems, eliminate one or two lines

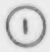
i. Generator



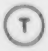
j. Motor



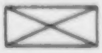
k. Instrument



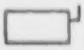
l. Power transformer



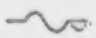
m. Controller



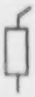
n. Isolating switch



o. Overcurrent device (fuse, breaker, thermal overload)



p. Switch and fuse



Information Sheet

Objective 8

Types of blueprint lines

a. Object lines (————————) show the main outline of the building including exterior walls, interior partitions, porches, patios, driveways, and interior walls; these lines should be the outstanding lines on a drawing.

b. Dimension lines (←————————→) are thin unbroken lines upon which building dimensions are placed.

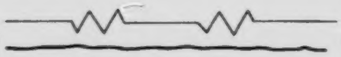
c. Extension lines (————————) extend, but do not touch, the object lines and permit dimension lines to be drawn between them.

d. Hidden lines (- -) are short dashes used to show lines that are not visible from that view.

e. Center lines (—— – ————— – —) are a series of short and long dashes used to designate the centers of doors, windows, and circles and to provide reference points for dimensioning.

f. Cutting-plane lines (↑——— – – ———↑) are heavy lines consisting of a series of one long and two short dashes with arrows at each end pointing away from the area that is cut away for the purpose of sectioning.

g. Section lines (////////////////////////////////) are a series of lines of various shapes or symbols used to depict an area that is a cross section of the whole object and also depict the type of material to be used in construction.



h. Break lines (————————) are used when an area cannot or should not be drawn in its entirety.

i. Leaders (←————————) are used to connect a note or dimension to a part of the building.

Objective 9

Typical electrical specifications

a. Minimum standards

Example: The contractor shall install the complete electrical system according to national and local electrical codes, as per plans and specifications.

b. Type of equipment

Example: All switches, duplex receptacles, and other outlets shall be in conduit (EMT will be acceptable). Electrical contractor shall furnish all lighting fixtures as per specifications or approved substitutes.

c. Type of installation

Example: Electrical service equipment shall be of units specified on plans or shall be approved substitutes or like quality. All work shall be done in coordination with other crafts.

d. Special instructions

Example: Receptacle circuits shall include an equipment grounding conductor of proper size.

Objective 10

Minimum requirements of electrical devices

a. Receptacles

Note: Refer to *NEC* Article 210, Part III.

- Rooftop heating, air conditioning, and refrigeration equipment must have a 125 GFCI volt receptacle within 25 feet (7.62m) of equipment

  Note: Refer to *NEC* Article 210.63

- Show windows must have one receptacle for each 12 linear feet (3.7 linear m)

  Note: Refer to *NEC* Article 210.62

b. Lighting—A unit load of not less than that specified in *NEC* Table 220.3(A) for occupancies listed therein shall constitute the minimum lighting load for each square foot (0.093 sqm) of floor area.

Note: Refer to *NEC* Article 220.3(B).

c. Disconnects—Are required by code for motors and appliances and each service, feeder, or branch circuit at the point where it originates and shall be legibly marked.

Note: Refer to *NEC* Article 110.22.

Objective 11

Steps for determining motor-circuit wire sizes

Note: *NEC* Table 430.148 gives normal amperages of single-phase motors, and Table 430.150 gives similar information for three-phase motors.

a. Determine motor size, voltage, and phase from print.

b. Determine full-load amperes from *NEC* Tables 430.148 and 430.150.

c. Determine circuit ampacity from *NEC* Article 430.22 (continuous-duty motors).

d. Determine wire insulation type, using *NEC* Table 310.13.

e. Determine wire size from *NEC* Table 310.16

Note: Refer to *NEC* Article 210.19 (FPN 4) and Article 215.2(4)(FPN 2).

Example: Table 1

Motors	Full-Load Amps per *NEC* 430.148 *NEC* 430.150	Calculated Circuit Ampacity per *NEC* 430.22	THW Wire Size *NEC* 310.16
1 hp 230 Volts 1 ϕ	8.0	10.0	#14
2 hp 230 Volts 3 ϕ	6.8	8.5	#14
3 hp 230 Volts 3 ϕ	9.6	12.0	#14
7.5 hp 230 volts 3 ϕ	22.0	27.5	#10
15 hp 230 volts 3 ϕ	42.0	52.5	#6

Objective 12

Load calculations

Note: The *NEC* allows only a specified number of conductors in a raceway. See Table 4 in Chapter Nine. Also, see Table 310.16.

a. Feeder calculations

- Feeder size is determined by branch circuit loads to be supplied.
- No reduction is permitted on the neutral conductor of 3 phase 4-wire wye systems serving electric discharge lighting, data processing, or similar loads. This is referred to as derating neutral.

  Note: Refer to *NEC* article 220.22

b. Branch circuit calculations

- Loads are classified in four separate groups:
  - — General lighting—Tables 220.3(A) and 220.11
  - — General purpose receptacle loads—220.3(9) and 220.13 Receptacles are rated at not less than 180VA
  - — Special appliance loads—220.3(B)(2)
  - — Motor loads—220.14, 430.22(A), 430.24, and 430.25
- Concerning temperature calculations, no conductor shall be used in such a manner that its operating temperature will exceed that designated for the type of insulated conductor involved.

  Note: See Tables 310.13 and 310.61 for maximum temperature. Tables 310.16 through 310.19 and 310.69 through 310.84, provide conductor sizes, types, ampacities, ambient temperatures, and number of associated conductors.

Objective 13

Voltage drop

Note: Refer to *NEC* Article 215.2(4)(FPN 2).

a. If voltage drop is too great, electrical equipment can overheat.

b. Voltage drop must be considered when feeder and branch circuit conductors are selected.

c. The equation for calculating single-phase voltage drop (VD) is:

$$VD = \frac{2L \times K \times I}{A}$$

d. The equation for calculating three-phase voltage drop is:

$$VD = \frac{L \times K \times I \times 1.732}{A}$$

e. The values that are used when determining voltage drop are:

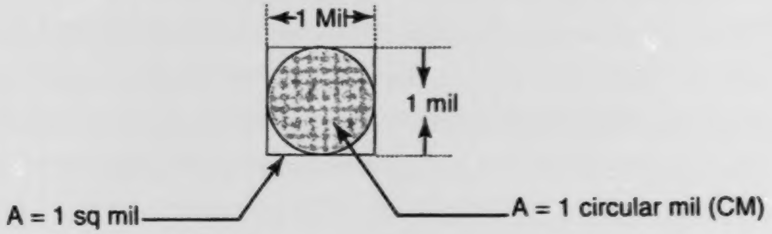
VD = Voltage drop in .... Volts (V)
L = One-way length of circuit conductor (for single-phase) in .... Feet (ft)
= Total length of circuit conductor (for 3-phase) in .... Feet (ft)
K = A constant for conductor material in .... CM-Ohm/ft
I = Current through conductor in .... Amperes (Amp, A)
A = Area of conductor in .... Circular Mils (CM)

Note: The Mil is a unit of measurement for length and is related to the inch by:

$$1 \text{ mil} = \frac{1}{1000} \text{ inch}$$

1000 mils = 1 inch

By definition, a wire with a diameter of 1 mil has an area of 1 circular mil (CM) as shown below.

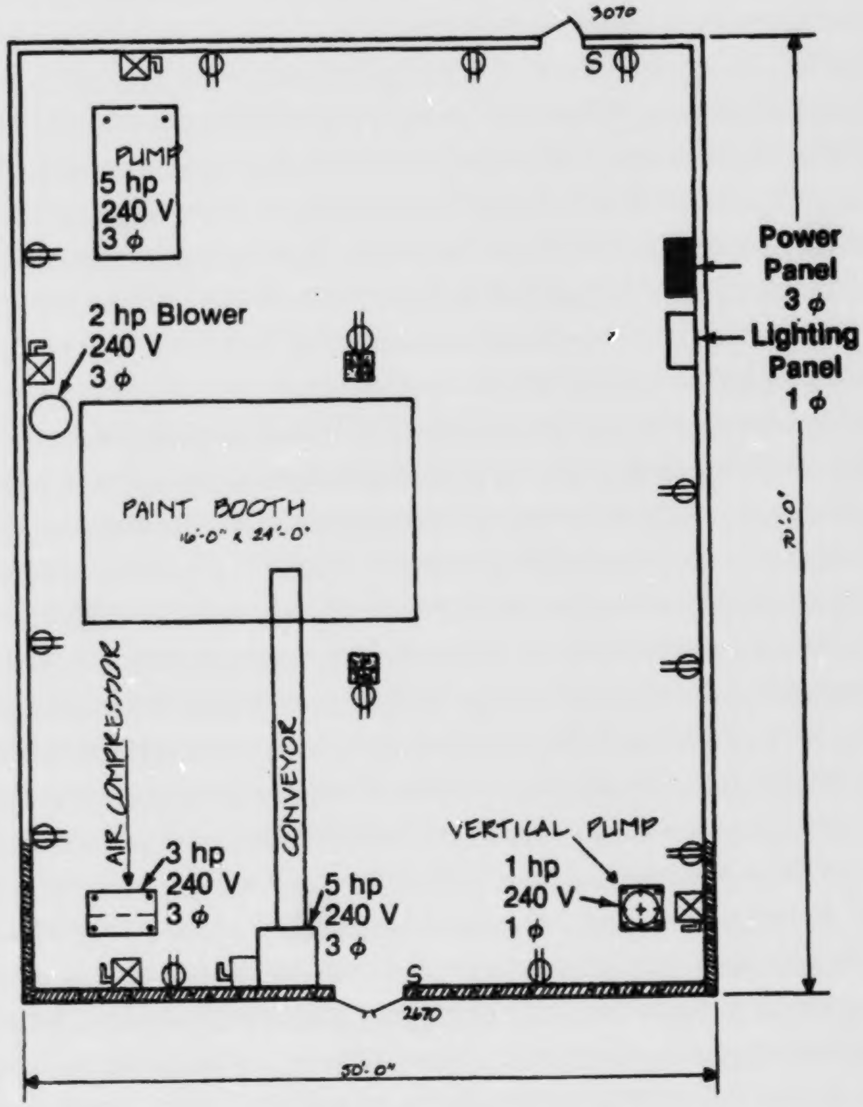


Information Sheet

Objective 14

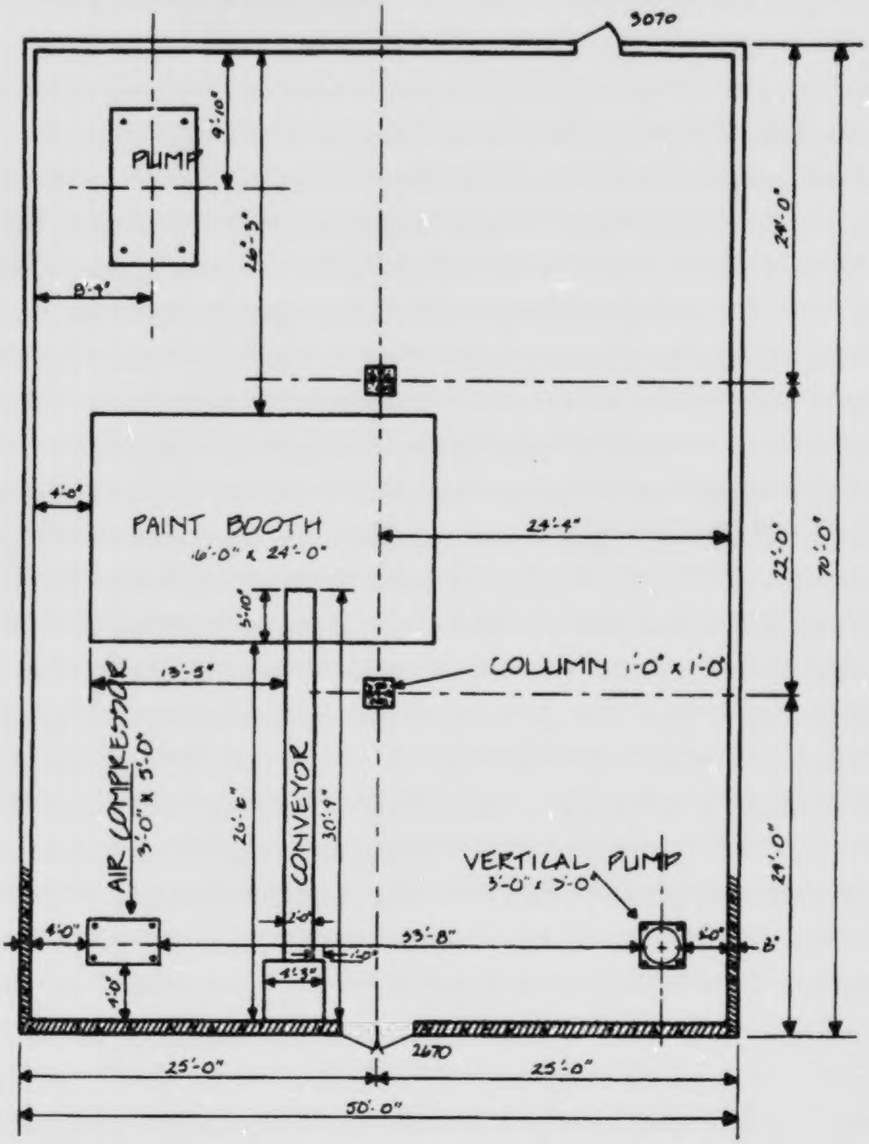
Types of blueprints

a. Electrical floor plan—Shows locations of switches, outlets, lighting, and special equipment

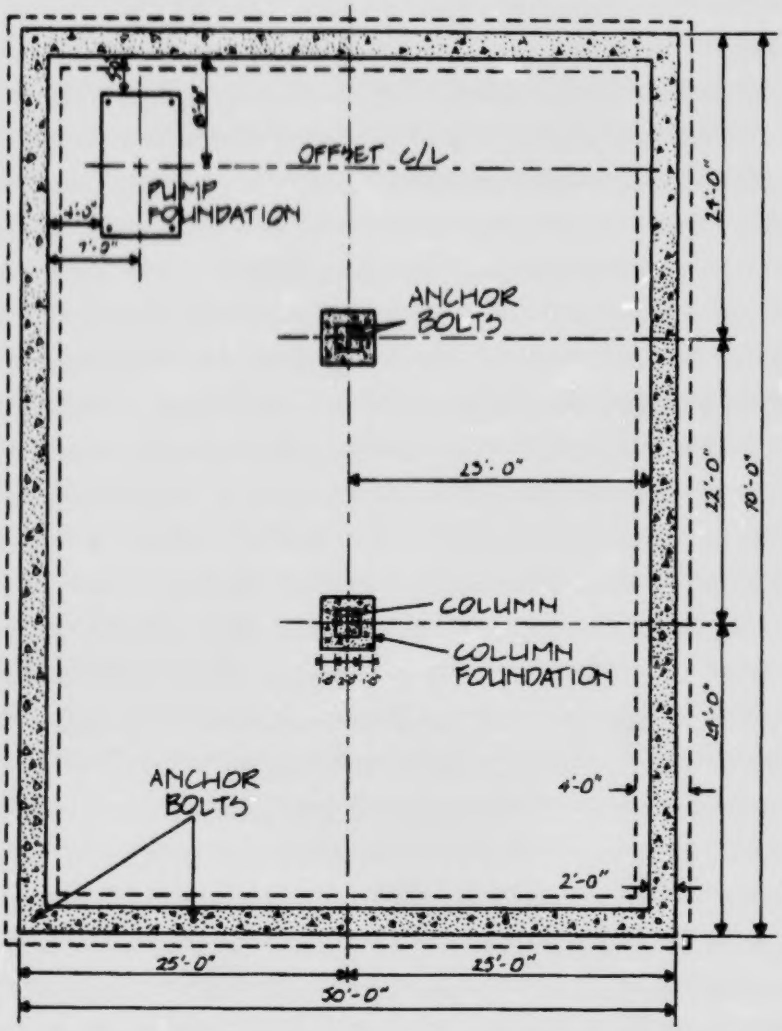

3070
S
PUMP
5 hp
240 V
3 ϕ
Power
Panel
3 ϕ
2 hp Blower
240 V
3 ϕ
Lighting
Panel
1 ϕ
PAINT BOOTH
16'-0" x 24'-0"
32'-0"
AIR COMPRESSOR
CONVEYOR
VERTICAL PUMP
3 hp
240 V
3 ϕ
5 hp
240 V
3 ϕ
1 hp
240 V
1 ϕ
S
2670
50'-0"

319

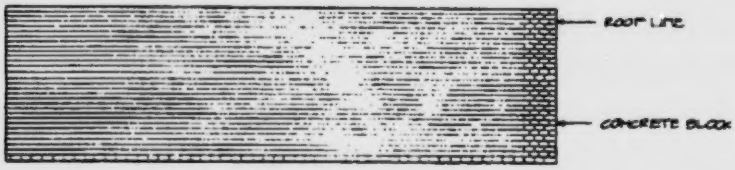
b. Floor plan—Similar to electrical but shows equipment, wall, and structural support locations


3070
PUMP
9'-10"
26'-3"
8'-9"
4'-0"
PAINT BOOTH
16'-0" x 24'-0"
24'-4"
3'-10"
13'-5"
COLUMN 1'-0" x 1'-0"
AIR COMPRESSOR
3'-0" x 5'-0"
26'-6"
CONVEYOR
30'-9"
VERTICAL PUMP
3'-0" x 3'-0"
4'-0"
2'-0"
33'-8"
1'-0"
4'-3"
2'-0"
8"
4'-0"
2670
24'-0"
22'-0"
70'-0"
24'-0"
25'-0"
25'-0"
50'-0"

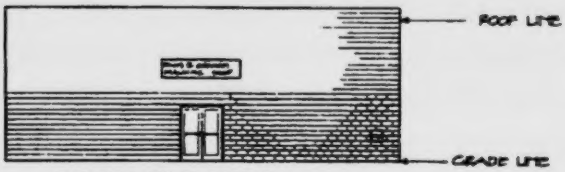
c. Foundation plan—Shows structural support characteristics of building which are pertinent when planning conduit runs


OFFSET C/L
PUMP FOUNDATION
4'-0"
7'-0"
ANCHOR BOLTS
24'-0"
25'-0"
22'-0"
70'-0"
COLUMN
COLUMN FOUNDATION
16 24 16
24'-0"
ANCHOR BOLTS
4'-0"
2'-0"
25'-0"
25'-0"
50'-0"

d. Elevations—Clarify placement of exterior lighting and power outlets'

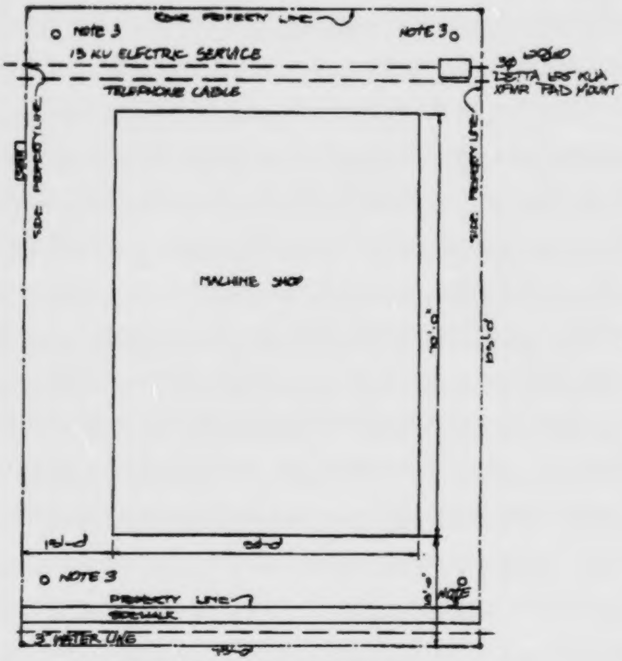

ROOF LINE
CONCRETE BLOCK

WEST ELEVATION


ROOF LINE
GRADE LINE

SOUTH ELEVATION

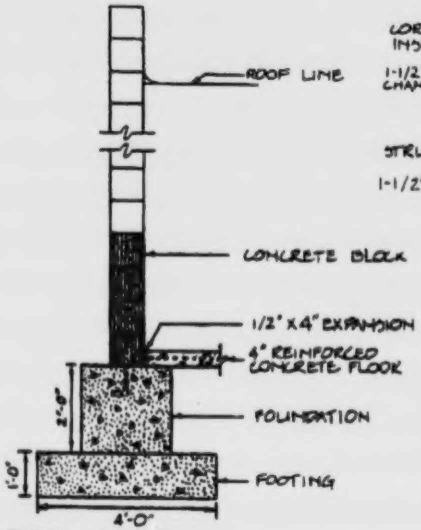
e. Plot plan—Shows location of building in relationship to layout of land and location of utilities and site lighting


REAR PROPERTY LINE
NOTE 3
NOTE 3
13 KV ELECTRIC SERVICE
TELEPHONE CABLE
DELTA 125 KVA
XFMR PAD MOUNT
SIDE PROPERTY LINE
SIDE PROPERTY LINE
MACHINE SHOP
NOTE 3
NOTE
PROPERTY LINE
SIDEWALK
3" WATER LINE

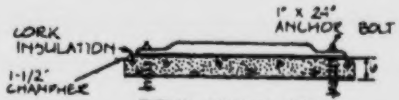
NOTE 3: 30' steel pole with one 250W HPS flood.

Information Sheet

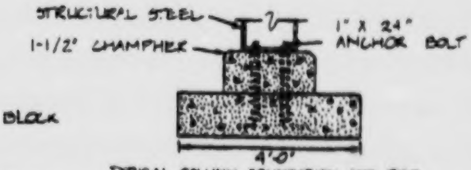
f. Details—Clarify specific installation requirements such as j-bolts for site lighting or special equipment mounting devices


ROOF LINE
CONCRETE BLOCK
1/2" X 4" EXPANSION
4" REINFORCED CONCRETE FLOOR
FOUNDATION
FOOTING
2'-0"
1'-0"
4'-0"

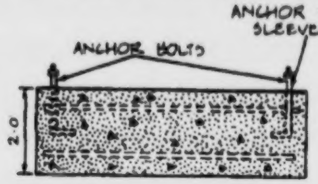
TYPICAL EXTERIOR WALL


1" X 24" ANCHOR BOLT
CORK INSULATION
1-1/2" CHAMPHER

TYPICAL MACHINE BASE


STRUCTURAL STEEL
1-1/2" CHAMPHER
1" X 24" ANCHOR BOLT
4'-0"

TYPICAL COLUMN FOUNDATION AND PIER


ANCHOR BOLT SLEEVES
ANCHOR BOLTS
2.0

TYPICAL MACHINE FOUNDATION

Unit 2 Tools and Equipment

Unit Contents

Student Components

Student Page

Learning Activities Sheet 2–3
Objective Sheet 2–5
Information Sheet 2–7

* Focus Assignment

Describe a Tool, and Suggest Changes to Increase Its Efficiency 23

* Job Sheets

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2—Bend EMT Stub-Ups 27
3—Make Back-To-Back Bends on One-Half-Inch EMT 31
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5—Bend and Install One-Half-Inch EMT 39
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7—Bend a Four-Point Saddle on One-Half-Inch EMT 47
8—Cut, Ream, Offset, and Install Connectors on One-Half-Inch PVC 51

* Focus Assignment and Job Sheets are located in Student Workbook 1.

Prerequisites:
None

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Do** Focus Assignment, "Describe a Tool and Suggest Changes to Increase its Efficiency."

☐ 4. **Study** Information Sheet, Objectives 1 through 8.

☐ 5. **Do** Job Sheet 1, "Bend, Cut, Ream, and Thread One-Half-Inch Rigid Metal Conduit."

☐ 6. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 7. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat Step 5.

☐ 7. **Do** Job Sheet 2, "Bend EMT Stub-Ups."

☐ 8. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 9. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat Step 7.

☐ 9. **Do** Job Sheet 3, "Make Back-to-Back Bends on One-Half-Inch EMT."

☐ 10. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 11. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat Step 9.

☐ 11. **Do** Job Sheet 4, "Make Offset Bends on One-Half-Inch EMT."

Learning Activities Sheet

☐	12.	**Stop**	Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 13. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 4 and repeat Step 11.
☐	13.	**Do**	Job Sheet 5, "Bend and Install One-Half-Inch EMT."
☐	14.	**Stop**	Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 15. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 5 and repeat Step 13.
☐	15.	**Do**	Job Sheet 6, "Bend a Three-Point Saddle on One-Half-Inch EMT."
☐	16.	**Stop**	Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 17. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 6 and repeat Step 15.
☐	17.	**Do**	Job Sheet 7, "Bend a Four-Point Saddle on One-Half-Inch EMT."
☐	18.	**Stop**	Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 19. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 7 and repeat Step 17.
☐	19.	**Do**	Job Sheet 8, "Cut, Ream, Offset, and Install Connectors on One-Half-Inch PVC."
☐	20.	**Stop**	Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 21. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 8 and repeat Step 19.
☐	21.	**Check**	With instructor for any additional assignments to be completed.
☐	22.	**Take**	Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.
☐	23.	**Stop**	Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Objective Sheet

Unit Objective

After completing this unit, the student should be able to identify and use tools and equipment found in electrical trades. The student should demonstrate these competencies by completing the focus assignment and job sheets, and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to tools and equipment with their definitions.
2. Identify types of conduit benders.
3. Identify wire termination tools.
4. Identify wire and cable pulling equipment.
5. Identify conduit cutting and threading tools.
6. Identify knockout cutters.
7. List power actuated tools used in the electrical trade.
8. List types of excavation equipment.
9. Describe a tool, and suggest changes to increase its efficiency. (Focus Assignment)
10. Bend, cut, ream, and thread one-half-inch rigid metal conduit. (Job Sheet 1)
11. Bend EMT stub-ups. (Job Sheet 2)
12. Make back-to-back bends on one-half-inch EMT. (Job Sheet 3)
13. Make offset bends on one-half-inch EMT. (Job Sheet 4)
14. Bend and install one-half-inch EMT. (Job Sheet 5)
15. Bend a three-point saddle on one-half-inch EMT. (Job Sheet 6)
16. Bend a four-point saddle one one-half-inch EMT. (Job Sheet 7)
17. Cut, ream, offset, and install connectors on one-half-inch PVC. (Job Sheet 8)

Information Sheet

Objective 1

Terms and definitions

a. **Backhoe**—Machine used to dig ditches on construction sites

b. **Bender**—Used to bend pipe used in electrical trades

c. **Cable bender**—Used to bend large conductors

d. **Cable cutters**—Used to cut conductors

e. **Cutting tools**—Used to cut conduit for electrical installations

f. **Fish tape**—Long tape of steel, nylon, or other material used to push or pull conductors into a raceway

g. **Hammer drill**—Used to bore through concrete

h. **Jet line**—Line sucked or blown through a conduit by positive or negative pressure so a rope or tape can be pulled through a conduit.

i. **Knockout cutter**—Used to cut holes, slots, and cuts in electrical boxes and studs

j. **Powder actuated device**—Uses charges that shoot studs and tie downs into concrete, metal, and wood

k. **Pulling equipment**—Used to pull multiple and large conductors through a conduit; may be manually or electrically operated

l. **Pulling lube**—Wax-based product that allows the conductors to pass through the conduit causing less friction

m. **Pulling sleeve**—Attaches around the end of conductors so they may be pulled through a conduit

n. **Strippers**—Used to remove insulation from conductors

o. **Threading tools**—Used to thread pipe so electrical fittings may be attached to conduit

Note: Electrical threads are straight; plumbing threads are tapered.

p. **Trencher**—Machine used to dig trenches

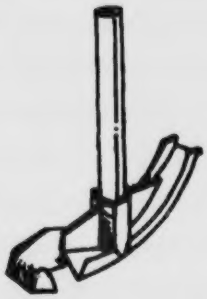
Objective 2

Types of conduit benders

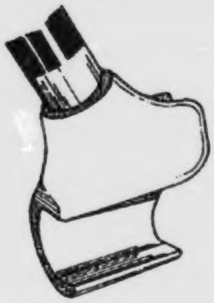
Note: There are four basic types of benders used in the electrical field: manual, hydraulic, mechanical, and PVC.

a. Manual conduit benders

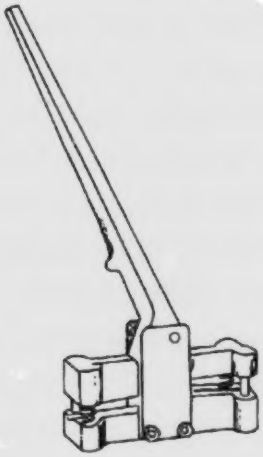
- EMT bender



- Hickey bender

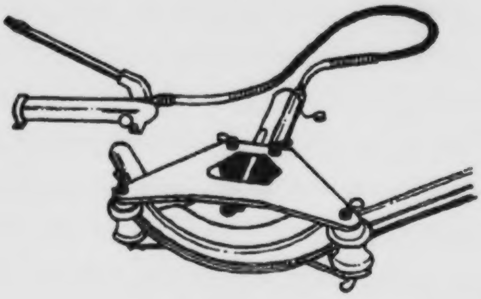


- One shot offset

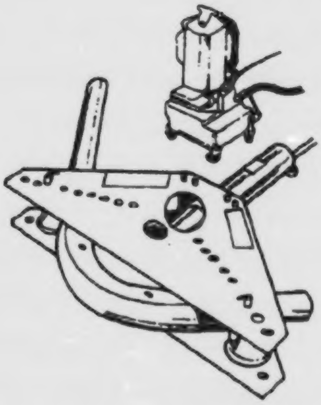


b. Hydraulic conduit benders

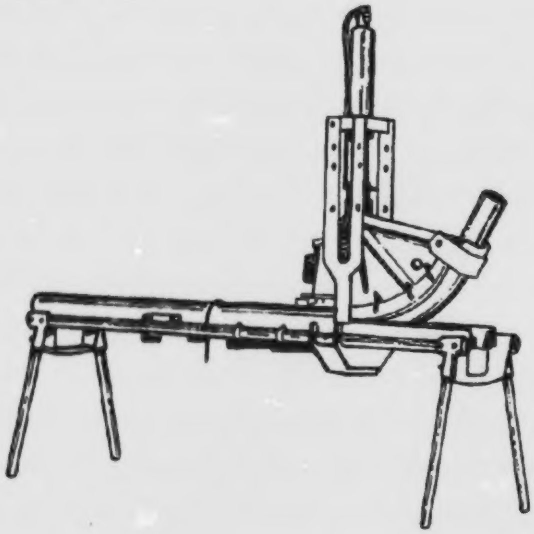
- Manual hydraulic bender



- Rigid bender

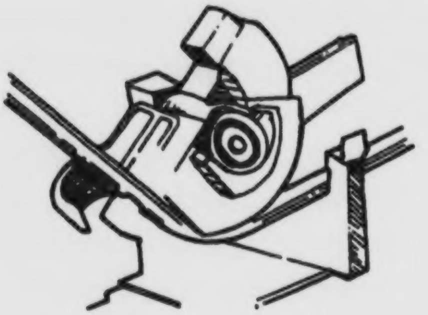


- Table bender

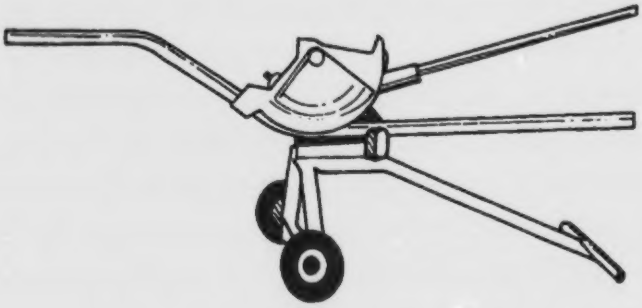


c. Mechanical conduit benders

- Rigid bender

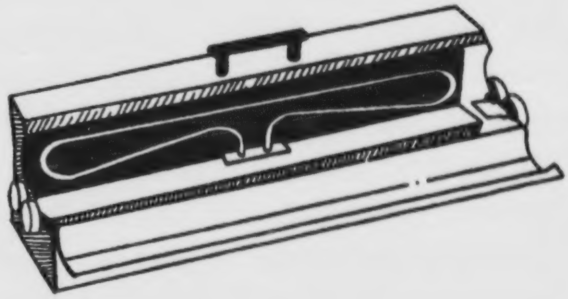


- EMT bender



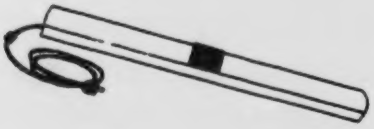
d. PVC Bending equipment

- Electric PVC heater

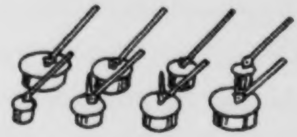


331

- PVC blanket



- PVC pipe plugs



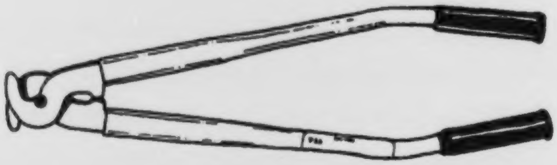
Objective 3

Wire termination tools

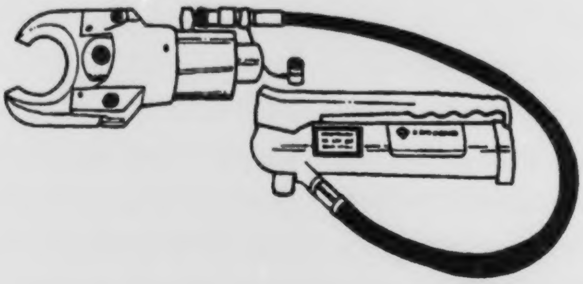
Note: When terminating copper, always use copper or copper clad lugs. When terminating aluminum, always use aluminum lugs.

a. Cable cutters

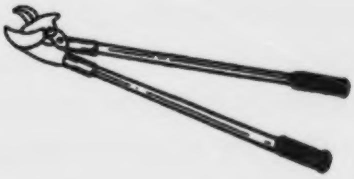
- Manual cutters



- Hydraulic cutters

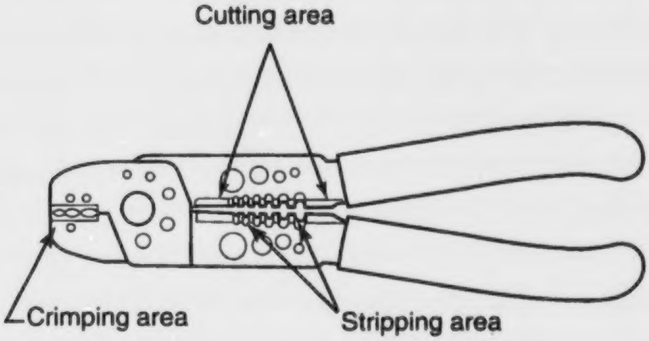


- Ratchet cutters

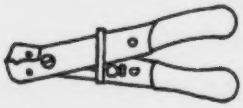


b. Wire strippers and crimpers

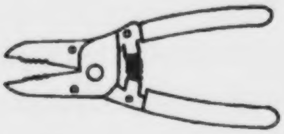
- Combination tool


Cutting area
Crimping area
Stripping area

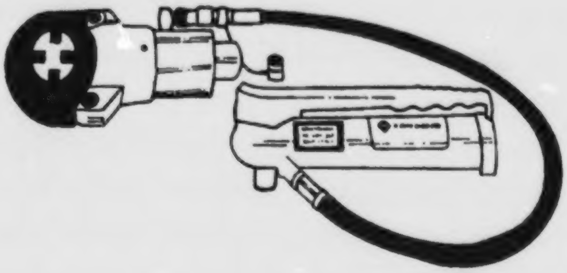
- Adjustable wire strippers



- Stripper/cutter

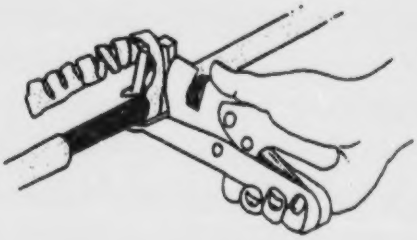


- Hydraulic crimper

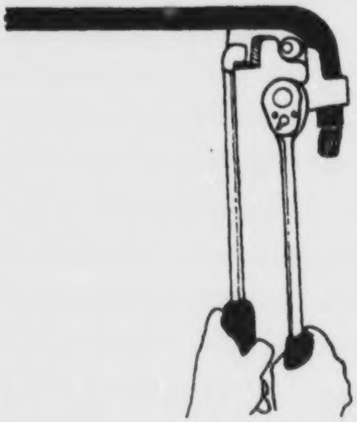


c. Cable stripper and bender

- Cable stripper



- Cable bender



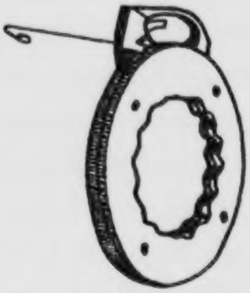
Information Sheet

Objective 4

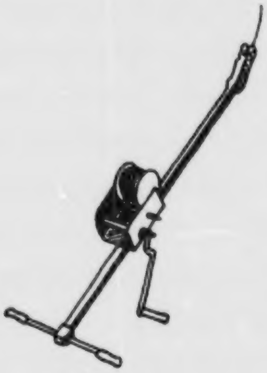
Wire and cable pulling equipment

Note: Pulling wire and cable through a conduit requires special tools. Tool use will vary depending on the conductor distance, size, and length.

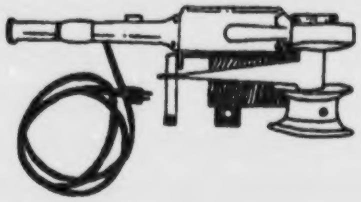
a. Fish tape



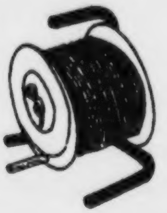
b. Manual puller



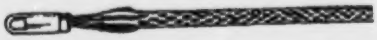
c. Electric puller



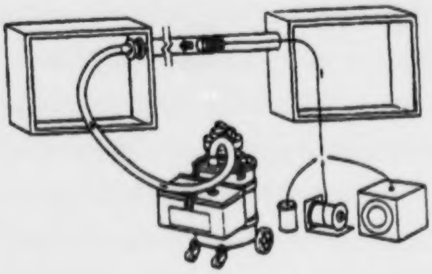
d. Pulling rope



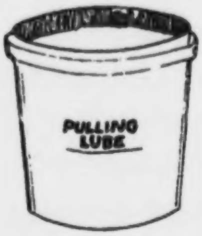
e. Pulling sleeve



f. Jet line



g. Pulling lube



Information Sheet

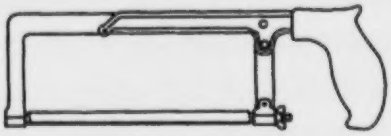
Objective 5

Conduit cutting and threading tools

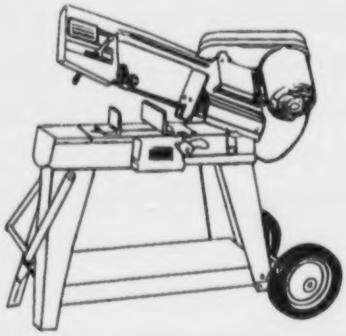
CAUTION: Equipment used in cutting and threading can be dangerous. Use caution when operating.

a. Cutting tools

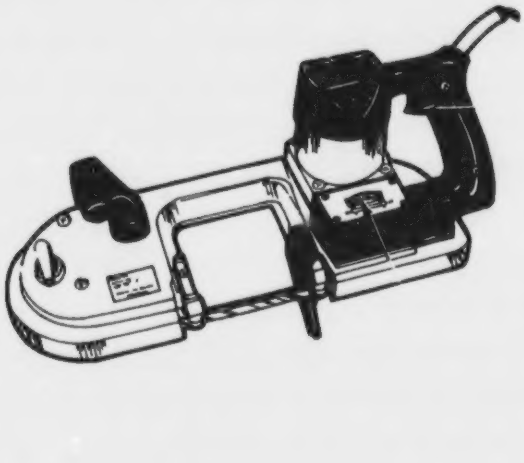
- Hacksaw



- Band saw



- Portable band saw



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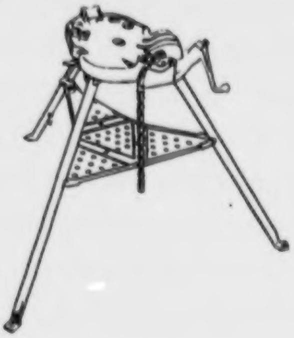
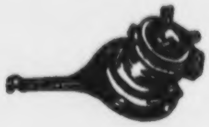
b. Threading tools

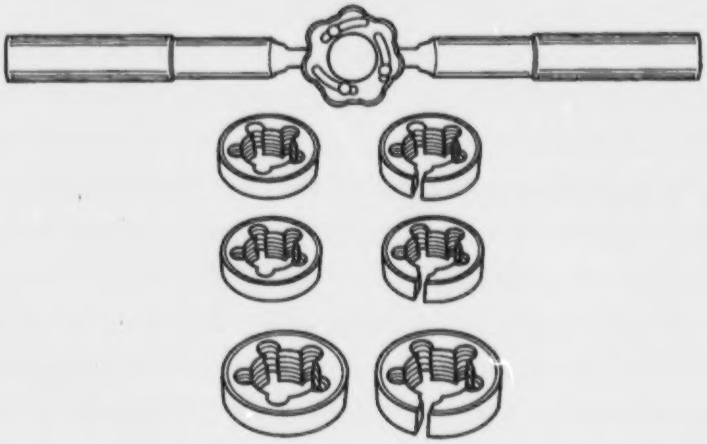
- Pipe stand



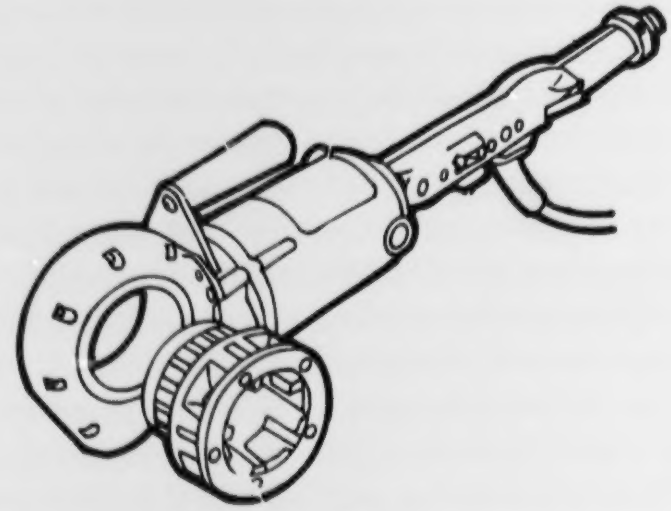
- Electric die set



- Manual die set



- Electric portable threader

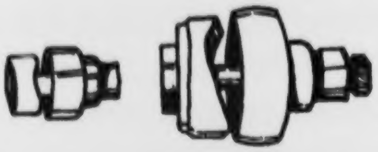


Objective 6

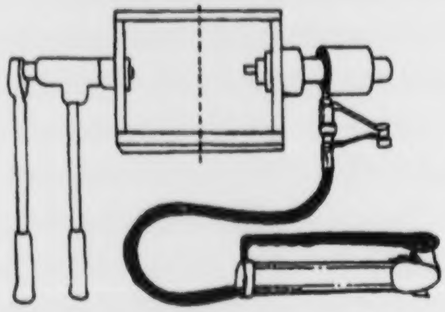
Knockout cutters

Note: Knockout cutters are used for making holes, slots, and cuts for electrical devices to be installed.

a. Manual K.O.



b. Ratchet K.O. (left) and hydraulic K.O. (right)



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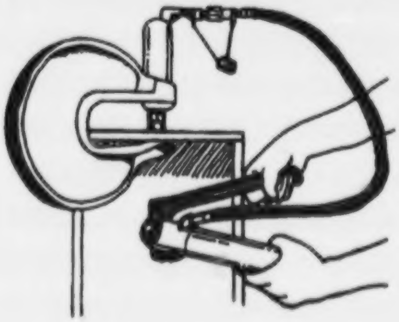
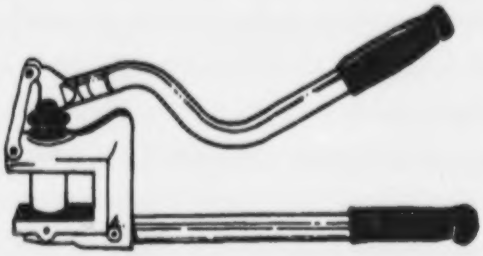
c. C-punch K.O.



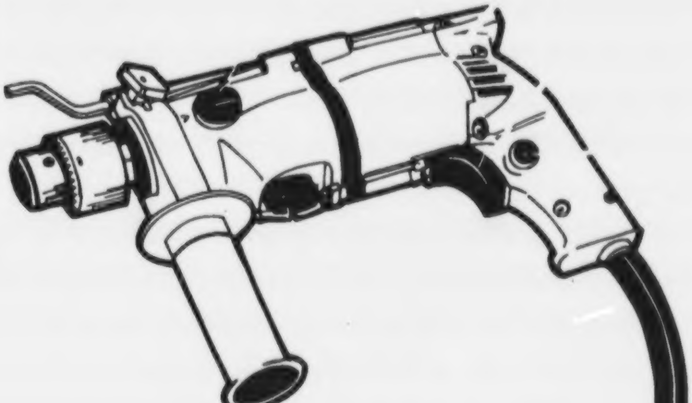
d. Stud punch



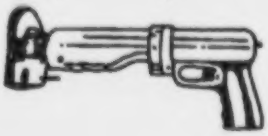
Objective 7

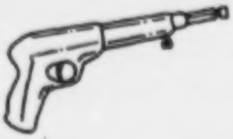
Power actuated tools

a. Hammer drill



b. Powder actuated device



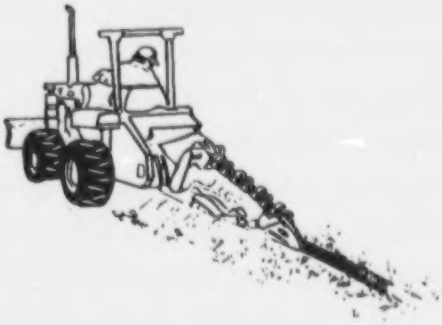


Objective 8

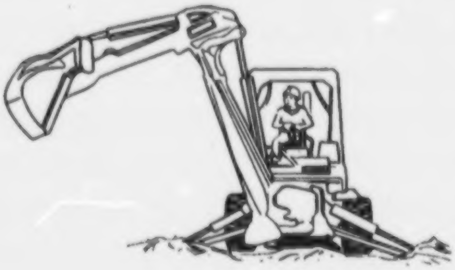
Excavation equipment

Note: Special training must be taken before operating excavation equipment Always have a locator on site before digging. This prevents cutting of gas, electrical, and telephone lines.

a. Trencher



b. Backhoe



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Unit Contents

Student Components

Student Page

Learning Activities Sheet 3–3
Objective Sheet 3–5
Information Sheet 3–7

* Job Sheets

1—Install an Overhead Raceway with Service Entrance Conductors to a Meter Base 53
2—Connect a Meter Base Assembly to a Load Center or Panel 57

* Job Sheets are located in Student Workbook 1.

Prerequisites:
None

Learning Activities Sheet

Student Name ____________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 8.

☐ 4. **Do** Job Sheet 1, "Install an Overhead Raceway with Service Entrance Conductors to a Meter Base."

☐ 5. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 6. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat Step 4.

☐ 6. **Do** Job Sheet 2, "Connect a Meter Base Assembly to a Load Center or Panel."

☐ 7. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 8. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat Step 6.

☐ 8. **Check** With instructor for any additional assignments to be completed.

☐ 9. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 10. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Objective Sheet

Unit Objective

After completing this unit, the student should be able to install 100 ampere service and determine switch gear, service entrance, drop clearances, laterals, and emergency standby systems. The student should demonstrate these competencies by completing the job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to service with their definitions.
2. Complete statements concerning *NEC* requirements for drop clearance and laterals.
3. Select true statements concerning switch boards and disconnects.
4. Match NEC exceptions for overcurrent protection devices with their correct statements.
5. Complete statements concerning grounding electrodes and ground fault.
6. Select true statements concerning service entrance devices.
7. Complete statements concerning emergency and standby systems.
8. State the procedure for balancing loads.
9. Install an overhead raceway with service entrance conductors to a meter base. (Job Sheet 1)
10. Connect a meter base assembly to a load center or panel. (Job Sheet 2)

Information Sheet

Objective 1

Terms and definitions

a. **CT**—Current transformer

b. **Disconnects**—Device used for breaking a circuit which may be fused or unfused

c. **Equipment grounding conductor**—Conductor used to connect non-current carrying metal parts of equipment to the system-grounded conductor or grounding-electrode conductor

d. **Ground**—Any good conductor that is connected to a common chassis with zero relative voltage

Note: Usually conductors are connected to the earth.

e. **Grounded**—Connected to the earth or to some conducting body that serves in place of the earth

f. **Grounded conductor**—System or circuit conductor that is intentionally grounded

g. **Grounding-electrode conductor**—Conductor used to connect grounding electrode to the equipment grounding conductor or to grounding conductor of circuit at service equipment or at source of separately derived system

h. **PT**—Potential transformer

i. **Service**—Where power is metered or is first attached to the structure

j. **Service drop**—Power conductors coming into building from power company

k. **Service panel**—Main control panel where voltage and current are distributed to different locations

Note: A service panel may also be referred to as a distribution panel or panelboard.

l. **Switch board**—Large single panel, frame, or assembly of panels on which are mounted, on the face or back or both, switches, overcurrent, and other protective devices, busses, and usually instruments; generally accessible from the rear as well as the front and intended to be installed in a cabinet

Objective 2

NEC requirements for drop clearance and laterals

a. There are two types of services used in the electrical trade: overhead and underground (lateral). Overhead services have different code requirements than underground.

b. Overhead services must be a specific size and have a minimum clearance from the finished grade.

c. The smallest conductors that can be used on a service are #8 copper and #6 aluminum. In special cases #12 hard-drawn copper may be used on branch or small equipment.

Note: Refer to *NEC* Article 230.23.

d. Clearances for service drops must comply with the *NEC*. Service drop conductors passing over a roof must be at least 8 feet (2.5m) above the roof.

Note: Refer to *NEC* Article 230.24.

e. There are two *NEC* exceptions which pertain to service drops.

- Exception No. 2 allows service drops to pass 3 feet (900mm) above the roof when the roof has a slope of 4 inches (100mm) in 12 inches (300mm) and the voltage is not in excess of 300 volts. When voltage is in excess of 300 volts, an 8 foot (2.5m) clearance must be used.

  Note: Refer to *NEC* Article 230-24.

- Exception No. 3 allows the service drop to be attached to the service mast when the drop does not pass over 4 feet (1.2m) of roof and the mast is at least 18 inches (450mm) above the roof line.

f. Service drop conductors rated at 600V or less have minimum clearances.

Note: Refer to *NEC* Article 230.24(B).

g. An underground service lateral must have a conductor size of at least #8 copper or #6 aluminum.

Note: Refer to *NEC* Article 230.31(B).

Objective 3

Switch boards and disconnects

a. A switch board is used for breaking the current or voltage from the meter base to the means of disconnection before being allowed to enter branch circuits.

b. Service disconnects are readily accessible for breaking the power entering a building. More than one disconnect may be used on a service.

Note: Refer to *NEC* Articles 230.71 and 230.72.

c. All service disconnects have overload protection. The disconnect must be large enough to carry the computed load it supplies.

Note: Refer to *NEC* Articles 230.79 and 230.90.

Objective 4

NEC exceptions for overcurrent protection devices

Note: Overcurrent protection devices must not be greater than the load carrying capacity of the service entrance conductors. There are four exceptions to NEC Article 230.90 for overcurrent protection for services.

a. Exception No. 1—An overcurrent protection device may be overfused to allow motors to attain running speed.

b. Exception No. 2—If not a standard size, the next higher standard size overcurrent protection device is used.

c. Exception No. 3—Two to six CBs or fuses may serve as overcurrent protection devices.

d. Exception No. 4—An overcurrent protection device must be rated to carry locked-rotor current of fire pump motors.

Objective 5

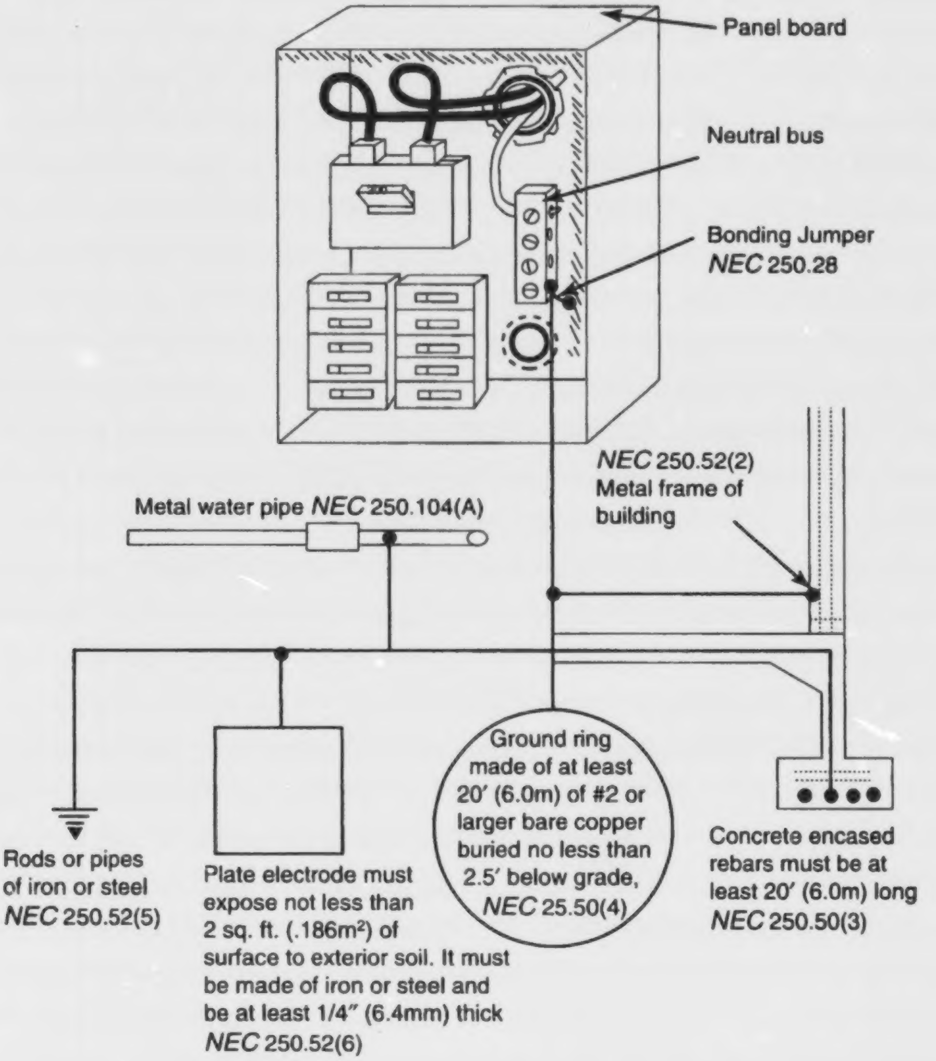
Grounding electrodes and ground fault

a. There are four types of electrode grounding systems used in electrical trades.

Note: Refer to *NEC* Article 250.52.

- Metal water pipe
- Building steel
- Reinforcing rod (20 feet minimum length)
- Ground ring

Figure 1—***NEC* approved grounding electrodes**


Panel board
Neutral bus
Bonding Jumper *NEC* 250.28
Metal water pipe *NEC* 250.104(A)
NEC 250.52(2) Metal frame of building
Rods or pipes of iron or steel *NEC* 250.52(5)
Plate electrode must expose not less than 2 sq. ft. (.186m²) of surface to exterior soil. It must be made of iron or steel and be at least 1/4″ (6.4mm) thick *NEC* 250.52(6)
Ground ring made of at least 20′ (6.0m) of #2 or larger bare copper buried no less than 2.5′ below grade, *NEC* 25.50(4)
Concrete encased rebars must be at least 20′ (6.0m) long *NEC* 250.50(3)

Note: If available within a premises, each of the items shown above must be bonded together to form the grounding system, *NEC* Art 250.53. In this arrangement, the grounded conductor is connected to the neutral bus.

b. A ground is required if the power company's secondary system is not efficiently grounded.

Note: Refer to *NEC* Article 250.24(3).

Objective 6

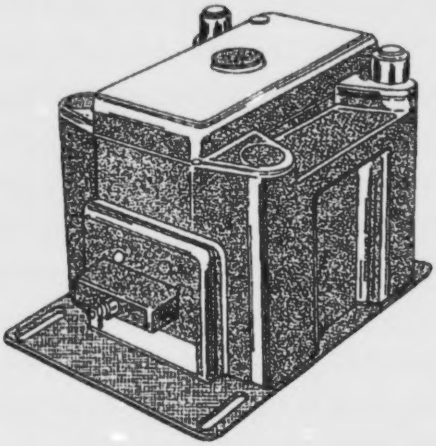
Service entrance devices

a. Conductor sizes of 1/0 or larger comprising each phase to neutral will be permitted to be connected in parallel. This means two conductors are used as one.

Note: Refer to *NEC* Article 310.4

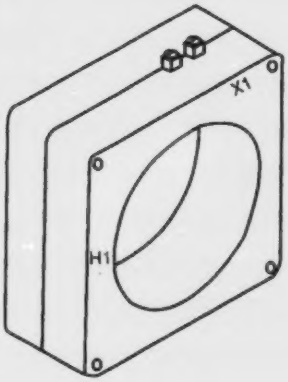
b. A potential transformer steps the voltage down so voltage measuring devices may be used.

Figure 2



c. A current transformer is a doughnut type device used in measuring current. An amprobe clamp-on ammeter is a current transformer. These are used in metering large services.

Figure 3



Objective 7

Emergency and standby systems

Note: Refer to *NEC* Article 700.

a. Separate, derived systems such as a generator or battery backup are used when the incoming voltage from the power company is interrupted or cut off. These systems are used in hospitals, factories, and stores where electricity is a must.

b. An automatic transfer switch senses a voltage loss and automatically switches a system to emergency power.

Objective 8

Balance loads—When balancing loads on panels, transformers, and switching equipment, an amprobe should be used to determine amperage on each circuit. The sum of the loads on each phase should be close to equal value.

Unit 4 Transformers

Unit Contents

Student Components

Student Page

Learning Activities Sheet 4–3
Objective Sheet 4–7
Information Sheet 4–9

* Focus Assignment

Analyze Utility Company Methods for Delivering Electrical Power . 61

* Assignment Sheets

1—Draw a Three-Phase Wye-Delta Transformer 63
2—Locate and List Two Exceptions on Transformer Room Construction for Dry Type Transformers 65
3—Locate and List Two Exceptions Concerning Oil-Insulted Transformers 67
4—Given Amperes, Calculate KVA on a Three-Phase System. ... 69

* Job Sheets

1—Test Transformer Turn Ratios 71
2—Test Transformer Insulation Resistance 75
3—Connect Transformer Primary and Secondary Windings in a Delta-Wye Configuration 79
4—Test and Compare Primary Apparent Power of a Transformer to Secondary Apparent Power 83

* Focus Assignment, Assignment Sheets, and Job Sheets are located in Student Workbook 1.

Prerequisites:
None

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Do** Focus Assignment, "Analyze Utility Company Methods for Deliverying Electrical Power."

☐ 4. **Study** Information Sheet, Objectives 1 through 3.

☐ 5. **Do** Assignment Sheet 1, "Draw a Three-Phase Wye-Delta Transformer."

☐ 6. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 7. If the evaluation is not satisfactory, repeat Steps 4 and 5.

☐ 7. **Study** Information Sheet, Objective 4.

☐ 8. **Do** Assignment Sheet 2, "Locate and List Two Exceptions on Transformer Room Construction for Dry Type Transformers."

☐ 9. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 10. If the evaluation is not satisfactory, repeat Steps 7 and 8.

☐ 10. **Study** Information Sheet, Objective 5.

☐ 11. **Do** Assignment Sheet 3, "Locate and List Two Exceptions Concerning Oil-Filled Transformers."

☐ 12. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 13. If the evaluation is not satisfactory, repeat Steps 10 and 11.

Learning Activities Sheet

☐	13.	**Study**	Information Sheet, Objectives 6 through 9.
☐	14.	**Do**	Assignment Sheet 4, "Given Amperes, Calculate KVA on a Three-Phase System."
☐	15.	**Stop**	Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 16. If the evaluation is not satisfactory, repeat Steps 13 and 14.
☐	16.	**Do**	Job Sheet 1, "Test Transformer Turn Ratios."
☐	17.	**Stop**	Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 18. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat Steps 16.
☐	18.	**Do**	Job Sheet 2, "Test Transformer Insulation Resistance."
☐	19.	**Stop**	Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 20. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat Step 18.
☐	20.	**Do**	Job Sheet 3, "Connect Transformer Primary and Secondary Windings in a Delta-Wye Configuration."
☐	21.	**Stop**	Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 22. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat Step 20.
☐	22.	**Do**	Job Sheet 4, "Test and Compare Primary Apparent Power of a Transformer to Secondary Apparent Power."
☐	23.	**Stop**	Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 24. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 4 and repeat Step 22.
☐	24.	**Check**	With instructor for any additional assignments to be completed.
☐	25.	**Take**	Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 26. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Objective Sheet

Unit Objective

After completing this unit, the student should be able to refer the the NEC to determine transformer locations and to identify specific transformer requirements. The student should demonstrate these competencies by completing the focus assignment, assignment sheets, and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to transformers with their definitions.
2. List basic types of transformers
3. Draw diagrams of the most commonly used voltage systems.
4. Select true statements concerning *NEC* requirements for dry type transformers.
5. Complete statements concerning *NEC* requirements for oil-filled transformers.
6. Select true statements concerning *NEC* requirements for askarel-filled transformers.
7. State the function of a buck and boost transformer.
8. Match *NEC* articles with their correct transformer locations.
9. Match *NEC* articles with the correct installation and termination of transformers.
10. Analyze utility company methods for delivering electrical power. (Focus Assignment)
11. Draw a three-phase wye-delta transformer. (Assignment Sheet 1)
12. Locate and list two exceptions on transformer room construction for dry type transformers. (Assignment Sheet 2)
13. Locate and list two exceptions concerning oil-filled transformers. (Assignment Sheet 3)
14. Given amperes, calculate KVA on a three-phase system. (Assignment Sheet 4)
15. Test transformer turn ratios. (Job Sheet 1)
16. Test transformer insulation resistance. (Job Sheet 2)
17. Connect transformer primary and secondary windings in a delta-wye configuration. (Job Sheet 3)
18. Test and compare primary apparent power of a transformer to secondary apparent power. (Job Sheet 4)

Information Sheet

Objective 1

Terms and definitions

a. **Ambient temperature**—The temperature in the area where any electrical equipment is to be located

Note: High temperature will raise the insulation temperatures and shorten the life of the electrical equipment.

b. **Buck and boost transformer**—A transformer that increases or decreases voltage

c. **Isolating transformer**—Insulates the primary circuit from the secondary circuit, but frequently with no voltage change

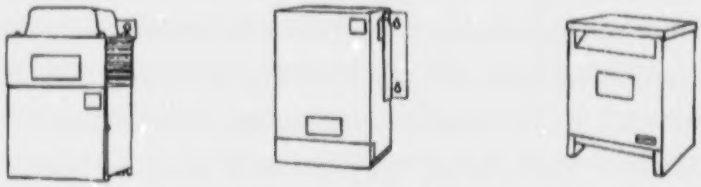
d. **Transformer vault**—Area in which transformers are installed for safety protection, usually constructed with concrete and fire-retardant doors

Objective 2

Basic types of transformers

a. Dry type—Do not have their core and coils submerged in oil

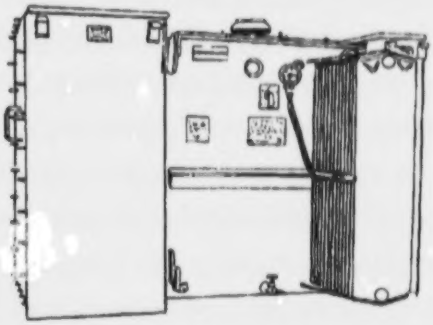
Figure 1



- Indoor
- Outdoor
- Floor mount

b. Oil-filled—Must have their core and coils submerged in oil

Figure 2



c. Askarel-filled—Filled with a liquid which produces gases from arcing

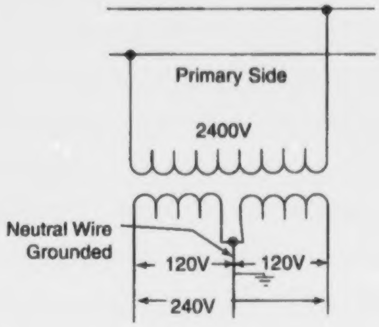
Note: Askarel-filled transformers are slowly being eliminated due to the presence of PCBs.

Objective 3

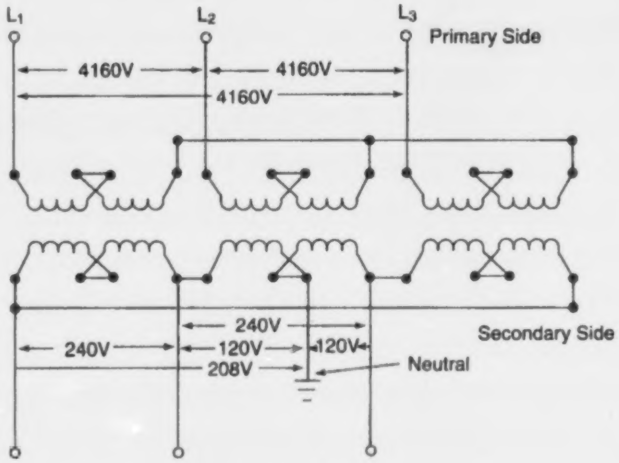
Most commonly used voltage systems

a. Single phase transformers

Figure 3


Primary Side
2400V
Neutral Wire Grounded
120V
120V
240V

b. Three phase transformers


L1
L2
L3
Primary Side
4160V
4160V
4160V
240V
240V
120V
120V
208V
Neutral
Secondary Side

Objective 4

***NEC* requirements for dry type transformers**

Note: Refer to *NEC* Article 450.21 and exceptions

a. Dry type transformers installed indoors rated at 112.5 KVA or less must have a fire resistant, heat-insulating barrier between transformer and combustible materials. If a barrier is not used and voltage is over 600V, a 12" (305mm) minimum from combustible material is used.

b. Dry type transformers do not require a 12" (305mm)separation of barrier if they are enclosed and are rated less than 112.5 KVA and will operate at 600V or less.

c. Dry type transformers rated over 35,000 volts must be installed in a vault.

Objective 5

NEC requirements for oil-filled transformers

a. Oil-filled transformers can be installed indoors and outdoors. When mounted indoors, oil-filled transformers must be mounted in a vault.

b. *NEC* Article 450.26 pertains to oil-insulated transformers which are installed indoors.

Note: Read complete article and exceptions.

c. *NEC* Article 450.27 pertains to oil-insulated transformers which are installed outdoors.

Note: Read complete article and exceptions.

Objective 6

NEC requirements for askarel-filled transformers

Note: Askarel-filled transformers release PCBs and should not be used on new installations.

a. Askarel-filled transformers are filled with a liquid called askarel which will not burn and is nonexplosive. Gases are produced as a result of arcing. A vent is required if the transformer is over 25 KVA.

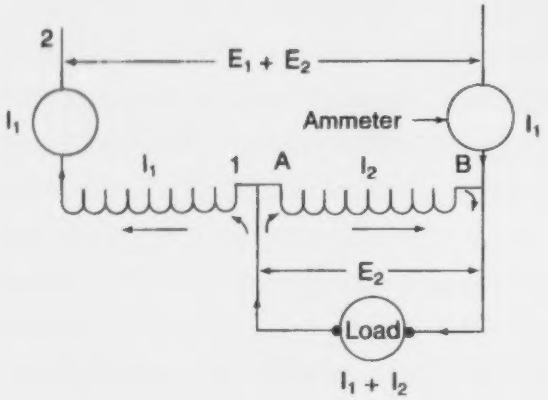
b. NEC Article 450.25 pertains to askarel-insulated transformers installed indoors.

Note: Read complete article on askarel transformers.

Objective 7

Function of a buck and boost transformer—It is used to increase or decrease voltage.

Note: The values used will depend on the line voltage and the amount of boost required. A buck and boost transformer is wired like an autotransformer.



Objective 8

NEC articles concerning transformer locations

Note: Some dry, oil-filled, and askarel-filled transformers require vaults for their insulation. Read the following articles and exceptions.

a. *NEC* Article 450.41 pertains to the location of transformer vaults.

b. *NEC* Article 450.42 pertains to walls, roofs, and floors.

c. *NEC* Article 450.43 pertains to doorways.

d. *NEC* Article 450.45 pertains to ventilation openings.

e. *NEC* Article 450.47 pertains to water pipes and accessories.

f. *NEC* Article 450.48 pertains to storage in vaults.

Objective 9

Installation and termination of transformers

a. Mounting of transformers must comply with the *NEC* on location, storage, and uses. Refer to *NEC* Article 450.2.

b. Grounding of transformers will comply with *NEC* Article 450.10.

c. Overcurrent protection may be installed on primary and secondary windings of transformers. Refer to:

   - *NEC* Article 240.4(F)
   - *NEC* Article 240.21, (B)(3), 240.21 (C)(1)(2)(5)

Unit Contents

Student Components

Student Page

Learning Activities Sheet 5–3

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Information Sheet 5–7

* Assignment Sheet

1—Determine the Number of Conductors Allowed to be Added to an Existing Conduit 85

* Job Sheets

1—Rough In a Wood Framed Wall 87
2—Install Outlet Boxes on Steel Rods 93
3—Install Outlet Boxes on Steel Studs Using Caddy Metal Stud Clips for Switch Boxes 97
4—Install Masonry Boxes in a Block Wall 101

* Assignment Sheet and Job Sheets are located in Student Workbook 1.

Prerequisites:
None

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet

☐ 3. **Study** Information Sheet, Objectives 1 through 5.

☐ 4. **Do** Assignment Sheet 1, "Determine the Number of Conductors Allowed to be Added to an Existing Conduit."

☐ 5. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 6. If the evaluation is not satisfactory, repeat Steps 3 and 4.

☐ 6. **Study** Information Sheet, Objectives 6 and 7.

☐ 7. **Do** Job Sheet 1, "Rough In a Wood Framed Wall."

☐ 8. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 9. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat Step 7.

☐ 9. **Do** Job Sheet 2, "Install Outlet Boxes on Steel Rods."

☐ 10. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 11. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat Step 9.

☐ 11. **Do** Job Sheet 3, "Install Outlet Boxes on Steel Studs Using Caddy Metal Stud Clips for Switch Boxes."

☐ 12. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 13. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat Step 11.

☐ 13. **Do** Job Sheet 4, "Install Masonry Boxes in a Block Wall."

☐ 14.	**Stop**	Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 15. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 4 repeat Step 13.
☐ 15.	**Check**	With instructor for any additional assignments to be completed.
☐ 16.	**Take**	Posttest provided by instructor. After the test has been evaluated, follow instructor's recommendations.
☐ 17.	**Stop**	Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next Learning Activities Sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Objective Sheet

Unit Objective

After completing this unit, the student should be able to rough in a commercial or industrial job. The student should demonstrate these competencies by completing the assignment sheet and job sheets, and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to rough-in with their correct definitions.
2. Select true statements concerning branch circuit and feeder installation.
3. Identify devices used in special circuit installations.
4. Select true statements concerning requirements for cable tray systems
5. Arrange in order the steps for determining the number of conductors allowed in a conduit, based on cross-sectional area.
6. List five types of acceptable wiring methods for commercial/industrial projects
7. Complete statements concerning optional calculations for additional loads to existing installations.
8. Determine the number of conductors allowed to be added to an existing conduit. (Assignment Sheet 1)
9. Rough in a wood framed wall. (Job Sheet 1)
10. Install outlet boxes on steel rods. (Job Sheet 2)
11. Install outlet boxes on steel studs using caddy metal stud clips for switch boxes (Job Sheet 3)
12. Install masonry boxes in a block wall. (Job Sheet 4)

Information Sheet

Objective 1

Terms and definitions

a. **Ampacity**—The current in amperes that a conductor can carry continuously under the conditions of use without exceeding its temperature rating

b. **Cable bender**—Mechanical or hydraulic device used to bend heavy conductors in panels and junction boxes

c. **Copper-clad aluminum**—Aluminum conductor with an outer coating of copper metallurgically bonded to the aluminum core

d. **Color coding**—Assigning colors to conductors based on their uses

e. **Covered**—Conductor encased within material of composition and thickness not recognized by the *National Electrical Code* as electrical insulation

f. **Cross-sectional area**—Area in square inches allowed in a raceway

g. **Drop chain**—Short length of small chain used to pull conductors or flexible conduit through an enclosed space or wall cavity

h. **Fish**—Establishing a connection between two points so a cable or length of flexible conduit can be installed

i. **Fish tape**—Long tape of steel, nylon, or other material used to push or pull conductors into a raceway

j. **Insulated**—Conductor encased within material of composition and thickness recognized by the *National Electrical Code* as electrical insulation

k. **Pipe chase**—Usually a vertical space between two floors, dedicated for the running of pipes and conduits between floors

l. **Power fish-tape system**—Vacuum or air pressure system for installing a pull cord in a raceway in order to pull in the heavy pull rope for heavy and long pulls

m. **Pull rope**—Strong rope of nylon or other substance used to pull heavy conductors into raceways

n. **Raceway**—An enclosed channel designed expressly for holding wires, cables, or busbars, with additional functions as permitted in the *National Electrical Code*

o. **Trim out**— Final stage in a wiring project; involves devices and plates, connecting and securing equipment, hanging fixtures, and testing the system

p. **Troubleshooting**—The systematic diagnosis of a malfunction

q. **Voltage rating**—Maximum and minimum voltage at which a device is designed to operate

r. **Winch**—Manual or motor-powered mechanical device used to pull conductors into a raceway

s. **Wire dispenser**—Movable rack used to hold one or more reels of wire so that wire can be easily pulled off reel and fed into raceway

t. **Wire-pulling compound**—Compound of soap and other substances used to lubricate conductors being pulled or pushed into a raceway

Objective 2

Branch circuit and feeder installation

a. When using multi-phase circuitry, balancing must take place to regulate the even flow of current on each of the phases. This is done by connecting an ammeter to the incoming conductor. By using the reading, circuits may be moved to balance the load by switching conductors with different phases.

b. Color coding for a high leg delta 4-wire system must be marked with orange color (refer to *NEC* Article 215.8) and must be located on center lug (refer to *NEC* Article 408.3E) when neutral is present.

c. When identifying neutrals, *NEC* Section 200.6 states that conductors not white must be marked with continuous white or gray tape, or white paint.

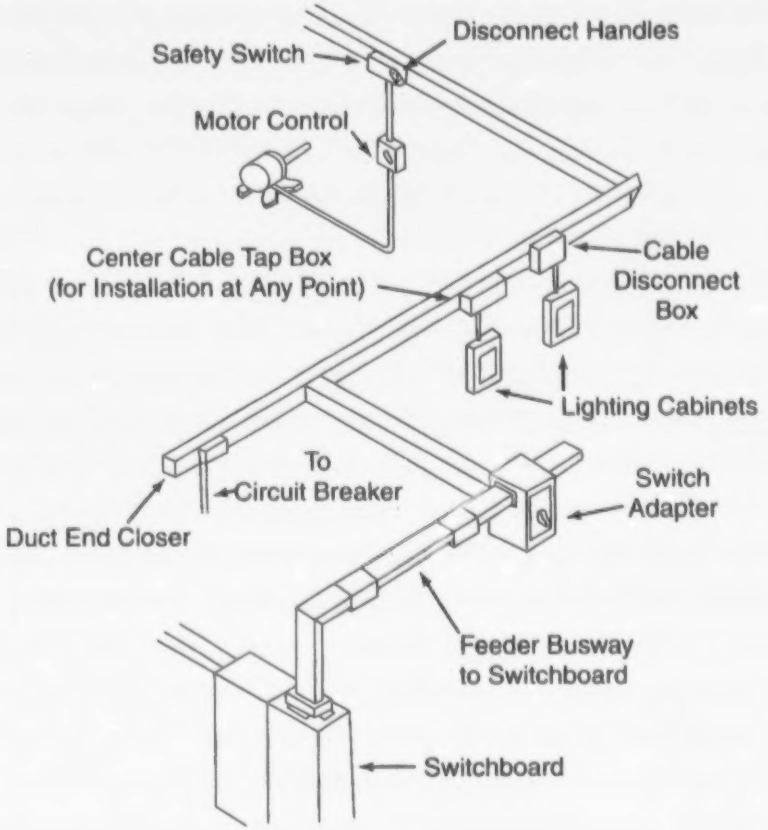
d. Temporary wiring and lighting must comply with *NEC* Article 527, which states that temporary power shall be equipped with GFI protection. Temporary lighting shall be protected from accidental contact or breakage by a suitable fixture or lampholder with a guard.

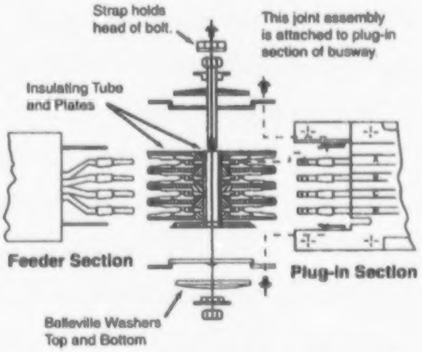
Objective 3

Devices used in special circuit installations

a. Bus duct

Figure 1


Disconnect Handles
Safety Switch
Motor Control
Center Cable Tap Box
(for Installation at Any Point)
Cable
Disconnect
Box
Lighting Cabinets
To
Circuit Breaker
Switch
Adapter
Duct End Closer
Feeder Busway
to Switchboard
Switchboard

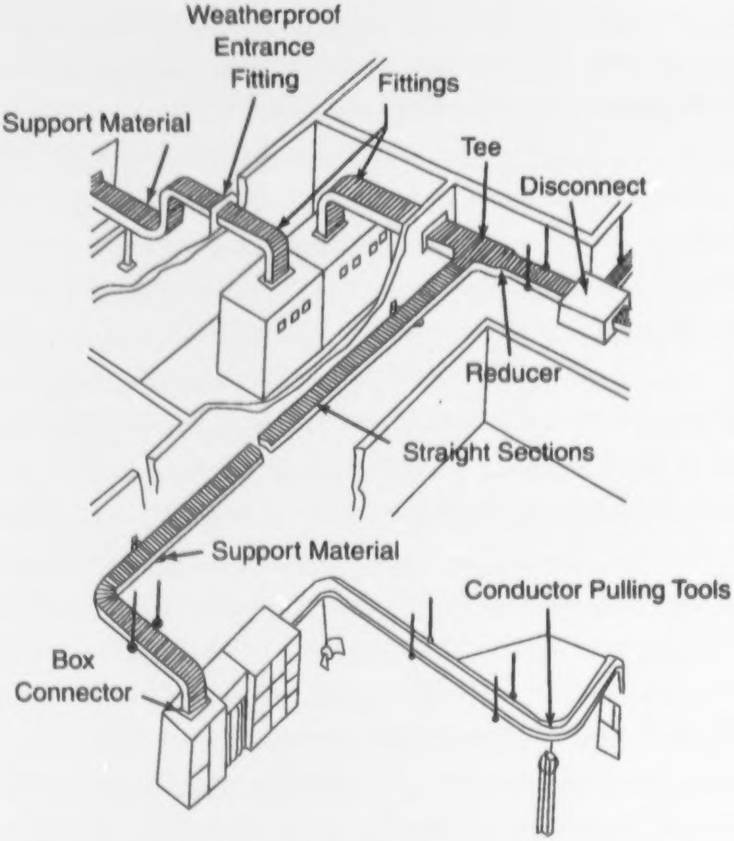

Strap holds
head of bolt.
This joint assembly
is attached to plug-in
section of busway.
Insulating Tube
and Plates
Feeder Section
Plug-In Section
Belleville Washers
Top and Bottom

One Bolt Joint Assembly

Used with permission of Cutler-Hammer Products/Eaton Corporation.

b. Cable tray

Figure 2


Weatherproof Entrance Fitting
Fittings
Support Material
Tee
Disconnect
Reducer
Straight Sections
Support Material
Conductor Pulling Tools
Box Connector

Objective 4

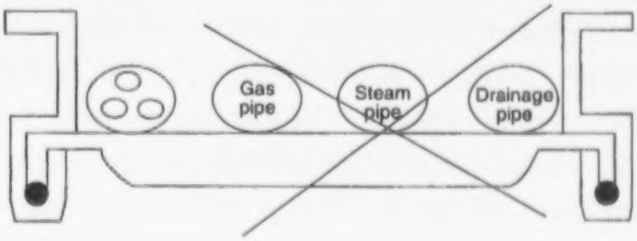
Requirements for cable-tray systems

a. Where conductors 1/0 through 4/0 are run in ladder type trays, the maximum rung spacing must not exceed 9 inches (230mm), *NEC* Section 392.3(B)(1)(a).

b. Single conductors must be 1/0 or larger, and cables must be identified as being listed and marked on the surface for use in cable trays. 392.3(B)(1)(a).

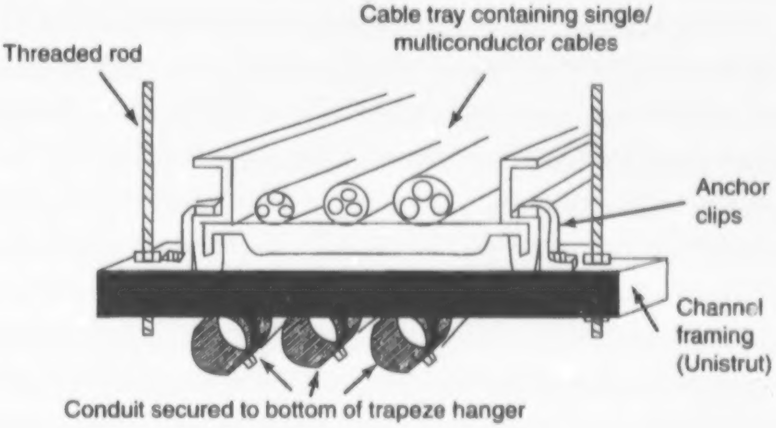
c. Electrical conductors must not be installed in the same raceways or cable-tray with steam, water, gas, air, or drainage pipes, *NEC* Section 300.8.

Figure 3


Gas pipe
Steam pipe
Drainage pipe

d. Cable-trays may be used as incidental support for raceways that are supported in accordance with *NEC* Art. 345, 346, 347, and 348. Section 392.6(J).

Figure 4


Threaded rod
Cable tray containing single/ multiconductor cables
Anchor clips
Channel framing (Unistrut)
Conduit secured to bottom of trapeze hanger

e. Solid fixed barrier of material compatible with the cable tray must separate multiconductor cables of over 600V and those of 600V or less where they are installed in the same cable tray, *NEC* Art 392.6(F)(2).

f. Minimum cross-sectional area of cable-tray must conform to the requirements of *NEC* Table 392.7(B).

g. Cable trays may be extended through partitions and walls, or vertically through platforms and floors if conditions of *NEC* Art 392.6(G) and 300.21 are met.

h. Proper grounding reduces hazards due to ground faults. *NEC* requires that all metallic cable trays be grounded in accordance with conductor enclosures in Art 250.

i. In portions of dairies, laundries, canneries, and other indoor wet locations, and in locations where walls are frequently washed, or surfaces of absorbent materials, the entire wiring system and fittings, where installed exposed, shall be mounted so that there is at least a 1/4" (6.35-mm) air-space between it and the wall or supporting surface *NEC* Art. 300.6(C).

j. Where single conductors are installed in triangular or square configuration in uncovered cable trays, with a maintained free air space of not less than 2.15 times one conductor diameter (2.15 X O.D.) of the largest conductor contained within the configuration and adjacent conductor configurations or cables, the ampacity of Nos. 1/0 and larger cables shall not exceed the allowable ampacity of two or three single insulated conductors rated 0 through 2000 volts supported on a messenger in accordance with Section 310.15(B), *NEC* Art 392.11(B)(4).

Objective 5

Steps for determining the number of conductors allowed in a conduit, based on cross-sectional area

a. Determine size of existing conduit.

b. Determine number and size of existing conductors.

c. Find area of conduit or tubing using Table 4, Chapter 9 of the *NEC*.

d. Compute total area occupied by existing conductors based on Table 5, Chapter 9 of *NEC*.

e. Determine number of conductors that may be added.

Example 1: An existing 1-inch (27) EMT conduit contains three #8 THHN conductors. Can four #12 THW conductors be added to this circuit or will a new conduit have to be run?

1-inch (27)EMT conduit with over two conductors not lead covered has an area of .346 square inches (222mm^2) (Table 4, Chapter 9).

#8 THHN has an area of .0366 sq. inches (23.61mm^2) (Table 5, Chapter 9).

.0366 sq. in.
x 3 conductors
.1098 sq. in.

#12 THW has an area of .0181 sq. inches (11.68mm^2) (Table 5, Chapter 9).

.0181 sq. in.
x 4 conductors
.0724

Total area required for conductors is:

.1098
+.0724
.1822

Since .1822 is less than .346, the four #12 THW conductors may be added.

Example 2: An existing 1-inch (27) Flexible Metal conduit contains five #8 THHN conductors. Can six #12 THW conductors be added to this circuit or will a new conduit have to be run?

1-inch (27) Flexible Metal conduit with over two conductors has an area of .327 sq. in. (211mm^2) (Table 4, Chapter 9)

#8 THHN has an area of .0366 sq. inches (23.61mm^2) (Table 5, Chapter 9).

.0366 sq. in.
x 5 conductors
.1830 sq. in.

#12 THW conductor has an area of .0260 sq. inches (Table 5, Chapter 9).

.0181 sq. in.
x 6 conductors
.1086 sq. in.

.1830
+.1086
.2916

Since .2916 is less than .3270, the six THW conductors can be added.

Note: Ampacity must be adjusted according to table 310.15(B)(2)(a) when more than 3 current carrying conductors are in a raceway.

Objective 6

Acceptable wiring methods for commercial and industrial projects

a. Mineral insulated metal sheathed cable (type MI).
NEC Art. 332 and Art. 300.

b. Electrical nonmetallic tubing.
NEC Art 362, see application section of Art 300.

c. Armored cable (type AC).
NEC Art 320.

d. Metallic clad (type MC).
NEC Art. 330, Art 300, Art 490, and Art 725.

e. Non-metallic sheathed cable (type NM, NMC, and NMS).
NEC Art 334.10, Art 300, and Art 310.

f. Non-metallic underground conduit with conductors.
NEC Art 354.

g. Intermediate metal conduit.
NEC Art 342.

h. Rigid metal conduit.
NEC Art 344.

i. Rigid nonmetal conduit (PVC).
NEC Art 352.

j. Electrical metallic tubing.
NEC Art 358.

k. Flexible metal conduit.
NEC Art 348.

Objective 7

Optional calculations for additional loads to existing installations

Note: For the purpose of allowing additional loads to be connected to existing feeders and services, it shall be permitted to use the actual KVA demand figures to determine the existing load on a service or feeder when all the following conditions are met. Refer to *NEC* Articles 220.35(1) through (3).

a. The maximum demand data is available in KVA for a minimum of a one year period.

b. The existing demand at 125 percent plus the new load does not exceed the ampacity of the feeders or rating of the service.

c. The feeder or service has overcurrent protection in accordance with sections 230.90 and 240.4 of the *NEC*.

Note: *NEC* Article 230.90 requires overcurrent protection in each ungrounded conductor. Article 240.4 requires that conductors other than flexible cords and fixture wires be protected against overcurrent in accordance with their ampacities as specified in Art 310.15 (A) through (G) and all applicable notes to these tables.

Unit Contents

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* Assignment Sheet

1—Locate Articles in the *NEC* Concerning Lighting Requirements 105

* Job Sheets

1—Change a Two-Lamp Ballast in a Fluorescent Fixture 107
2—Change Sockets in a Fluorescent Fixture 109
3—Change an HID Ballast 111
4—Change a Quartz Lamp 113

* Assignment Sheet and Job Sheets are located in Student Workbook 1.

Prerequisites:
None

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet

☐ 3. **Study** Information Sheet, Objective 1.

☐ 4. **Do** Assignment Sheet 1, "Locate Articles in the *NEC* Concerning Lighting Requirements."

☐ 5. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 6. If the evaluation is not satisfactory, repeat Steps 3 and 4.

☐ 6. **Study** Information Sheet, Objectives 2 through 9.

☐ 7. **Do** Job Sheet 1, "Change a Two-Lamp Ballast in a Fluorescent Fixture."

☐ 8. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 9. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat Step 7.

☐ 9. **Do** Job Sheet 2, "Change Sockets in a Fluorescent Fixture."

☐ 10. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 11. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat Step 9.

☐ 11. **Do** Job Sheet 3, "Change an HID Ballast."

☐ 12. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 13. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat Step 11.

☐ 13. **Do** Job Sheet 4, "Change a Quartz Lamp."

☐ 14. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 15 If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 4 and repeat Step 13.

Learning Activities Sheet

☐ 15. **Check** With instructor for any additional assignments to be completed.

☐ 16. **Take** Posttest provided by instructor. After the test has been evaluated, follow instructor's recommendations.

☐ 17. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next Learning Activities Sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Objective Sheet

Unit Objective

After completing this unit, the student should be able to troubleshoot and repair lighting fixtures. The student should demonstrate these competencies by completing the assignment sheet and job sheets, and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to lighting with their definitions.
2. List basic types of lighting.
3. Select true statements concerning characteristics of incandescent lighting.
4. Complete statements concerning characteristics of fluorescent lighting.
5. Complete statements concerning characteristics of high intensity discharge lamps.
6. Complete statements concerning characteristics of ballast.
7. List methods of calculating light.
8. Complete statements concerning calculating branch circuits and voltage.
9. Select true statements concerning switching systems.
10. Locate articles in the *NEC* concerning lighting requirements. (Assignment Sheet 1)
11. Change a two-lamp ballast in a fluorescent fixture. (Job Sheet 1)
12. Change sockets in a fluorescent fixture. (Job Sheet 2)
13. Change an HID ballast. (Job Sheet 3)
14. Change a quartz lamp. (Job Sheet 4)

Information Sheet

Objective 1

Terms and definitions

a. **B**—Blue lamp

b. **Ballast**—Transformer used in lighting circuits

c. **Cathode**—Coiled coil or triple coil tungsten wire at each end of lamp which is coated with material that emits electrons

d. **Coefficient**—The square root of the ratio of the power reflected from a surface to the power incident of the same surface

e. **CW**—Cool white lamp

f. **D**—Daylight lamp

g. **Fluorescent lighting**—Electric discharge lighting

h. **FC**—Footcandles

i. **G**—Green lamp

j. **HID**—High intensity discharge

k. **Incandescent lighting**—Consists of a filament which is a highly refractory conductor mounted in a transparent or translucent glass bulb

l. **Lumen**—A unit of light emitted from a point light source of one candle through a unit solid angle

m. **PK**—Pink lamp

n. **Photocell**—Light activated switch

o. **Photometer**—Instrument used to determine lumens

p. **Phosphor**—Coating inside a fluorescent bulb that determines the color of light

q. **W**—White lamp

r. **WW**—Warm white lamp

Objective 2

Basic types of lighting

a. Incandescent

b. Fluorescent

c. High intensity discharge (HID)

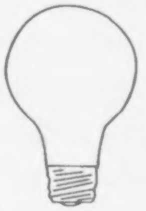
Objective 3

Characteristics of incandescent lighting

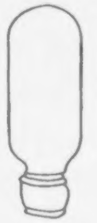
a. Incandescent lamps each have the lowest efficiency rating of any lamps, but are the most popular type used because of the low cost.

b. Incandescent lamps come in many different sizes and shapes.

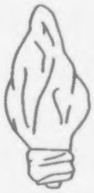
Examples:



General Use



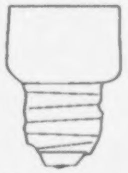
Tube



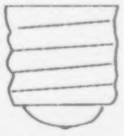
Flame

c. Incandescent lamps have different bases.

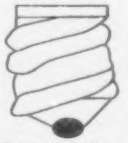
Examples:



Medium or
Edison based



Mogul



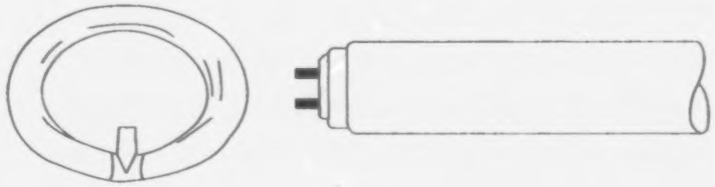
Candelabra

Objective 4

Characteristics of fluorescent lighting

a Classifications of fluorescent lamps is determined by the type, length or wattage, shape and color.

Example:

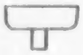


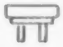
b The color of a fluorescent lamp depends on the phosphor used inside the lamp.

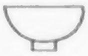
Note: Different colors are usually marked on the lamp as D—daylight, W—white, CW—cool white, WW—warm white, B—blue, PK—pink, and G—green.

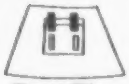
c. There are four types of contacts found on tube bases of fluorescent lamps:

Examples:


Single Pin


Bi-Pin


Recessed Double Contact Pin


Four Pin

d There are three types of fluorescent tubes: preheat, rapid-start, and instant-start.

- Preheat systems (original design) contain a preheat circuit that applies power to lamp electrodes, which is necessary to establish the electrical arc within the lamp.
- In rapid-start systems (today's most popular design), the lamp electrodes are automatically preheated by means of heater windings built into the lamp ballast.
- Instant-start systems produce light instantly by providing open circuit voltage to the lamp electrodes at about three times the normal lamp operating voltage, to initiate the arc.

Objective 5

Characteristics of high intensity discharge (HID) lamps

a. There are four basic types of HID lamps used in the lighting industry: mercury, metal halide, high pressure sodium, and low pressure sodium.

b. Mercury and metal halide lamps have an additional electrode to assist lamp starting while high pressure sodium, low pressure sodium, and some newer metal halide lamps have no starting electrodes.

c. There are disadvantages and advantages when using high intensity discharge lighting.

- Disadvantages—HID lighting takes longer to reach full output. When power is lost, HID lighting goes through a cooling period before coming back on. Emergency back-up lighting is generally used when an HID system is in operation.

Light Source	Warm-Up Time	Restrike Time
Mercury Vapor	5-7 minutes	3-6 minutes
Metal Halide	2-5 minutes	10-20 minutes
High Pressure Sodium	3-4 minutes	1/2-1 minute
Low Pressure Sodium	7-10 minuts	3-12 minutes

- Advantages—HID lighting provides greater lumens per watt for the cost of operation. HID lighting is less expensive to operate than any other source of lighting. HID lighting also has fewer maintenance problems.

Objective 6

Characteristics of ballast

a. In all fluorescent lighting systems, the ballast performs two basic functions:

- To start the lamp, it provides the proper voltage to establish an arc between the two electrodes
- While the lamp is in operation, it regulates the electric current flowing through the lamp to stabilize light output

b. There are three types of ballast: electromagnetic, hybrid, and electronic. (Figure 1 and 2)

Figure 1

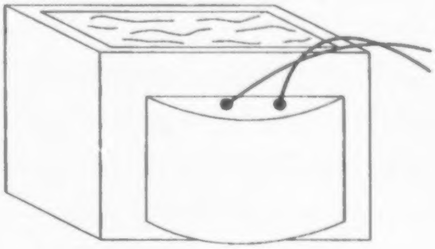
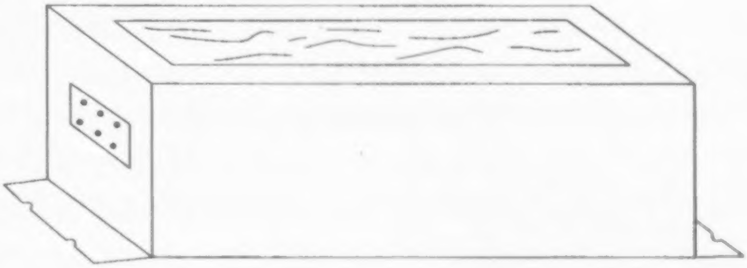


Figure 2



- Electromagnetic ballast
  - — Contain a core of stacked steel laminations surrounded by wound coils of insulated copper or aluminum wire.
  - — This design functions both as a voltage transformer and a current limiter.
- Hybrid ballast
  - — Basically the same as electromagnetic ballast, but incorporates electronic circuitry to disconnect the cathode heater windings after the lamp ignites
- Electronic ballast
  - — Operates the lamp at a frequency of 20,000 Hz or greater, rather than the 60 Hz operation of electromagnetic or hybrid types.

— This is accomplished through the use of electronic circuitry, which generally results in a more efficient, smaller, lighter, and quieter ballast.

Note: In order to choose a ballast for a particular application, there are three pieces of information that must be supplied. These are lamp type, number of lamps the ballast must operate, and input voltage to the lighting system. Once these three criteria are identified, a ballast can be chosen based on its performance characteristics.

Objective 7

Methods of calculating light

a. Footcandles may be calculated by the following formula when the lumens and square feet are known.

Note: The intensity of light at a distance from the source is expressed in footcandles or in lumens.

$$\text{Footcandles} = \frac{\text{Lumens on a Surface}}{\text{Area of Surface in Square Feet}}$$

b. To obtain the output of a light source in lumens when spherical candle power is known, use the formula

$F = 12.57 \times I$ LM

c. A photometer is an instrument used in determining the luminous intensity, in candles, of a light source.

Objective 8

Calculating branch circuits and voltage

a. When calculating branch circuit lighting loads, a unit load of not less than that specified in Table 220.3(A), shall constitute the minimum load for each square foot (0.093-m^2) of floor area.

b. If line voltage is higher or lower than that for which the ballast was designed, this condition can affect lamp life, ballast life, and lamp light output. Ballasts should operate within $\pm 7^1/_2\%$ of rated voltage.

Objective 9

Switching systems

a. Switches, photocells, and magnetic lighting contactors may be used to control lighting circuits.

b. Switches may be used for controlling lighting circuits when the amperes are within the rating of the switch.

c. A photocell is a switch activated by light or sunlight. It may be used for controlling lights within its ampacity or can control a lighting contactor.

d. Lighting contactors are used when photocells and switches cannot control the lighting amperage. Photocells and switches may then be used as control circuits for a lighting contactor.

e. Switches and dimmers may be used on fluorescent and HID lighting. The output of fluorescent or HID lamps can be adjusted by holding a constant voltage on the cathodes and controlling the current passing through the lamp. Thyrations, silicon-controlled rectifiers, and autotransformers can provide this type of control.

Note: Dimmers require a special ballast for fluorescent lights.

Unit Contents

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Objective Sheet 7–7

Information Sheet 7–9

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3—Use the *National Electrical Code* to Answer Questions About Motor Control Circuits 119
4—Distinguish Between Motor Starters and Contactors 121
5—Answer Questions About Uses of Contactors and Motor Starters 125

* Job Sheets

1—Disassemble, Inspect, and Clean a Motor 127
2—Identify Run, Common, and Start Terminals on Hermetically Sealed Motors 131
3—Test Capacitors with an Ohmmeter 135
4—Wire a Three-Phase Motor for Dual Voltages 137
5—Perform Maintenance on a Magnetic Contactor 139

* Assignment Sheets and Job Sheets are located in Student Workbook 1.

Prerequisites:
None

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet

☐ 3. **Study** Information Sheet, Objectives 1 and 2.

☐ 4. **Do** Assignment Sheet 1, "Interpret Nameplate Information."

☐ 5. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 6. If the evaluation is not satisfactory, repeat Steps 3 and 4.

☐ 6. **Study** Information Sheet, Objectives 3 through 13.

☐ 7. **Do** Assignment Sheet 2, "Describe Remedies for Common Motor Problems."

☐ 8. **Study** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 9. If the evaluation is not satisfactory, repeat Steps 6 and 7.

☐ 9. **Do** Assignment Sheet 3, "Use the *National Electrical Code* to Answer Questions About Motor Control Circuits."

☐ 10. **Study** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 11. If the evaluation is not satisfactory, repeat Steps 6 and 9.

☐ 11. **Study** Information Sheet, Objectives 14 through 21.

☐ 12. **Do** Assignment Sheet 4, "Distinguish Between Motor Starters and Contactors."

Learning Activities Sheet

☐ 13. **Study** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 14. If the evaluation is not satisfactory, repeat Steps 11 and 12.

☐ 14. **Do** Assignment Sheet 5, "Answer Questions About Uses of Contactors and Motor Starters."

☐ 15. **Study** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 16. If the evaluation is not satisfactory, repeat Steps 11 and 14.

☐ 16. **Study** Information Sheet, Objectives 22 through 24.

☐ 17. **Do** Job Sheet 1, "Disassemble, Inspect, and Clean a Motor."

☐ 18. **Study** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 19. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat Step 17.

☐ 19. **Do** Job Sheet 2, "Identify Run, Common, and Start Terminals on Hermetically Sealed Motors."

☐ 20. **Study** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 21. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat Step 19.

☐ 21. **Do** Job Sheet 3, "Test Capacitors With An Ohmmeter."

☐ 22. **Study** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 23. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat Step 21.

☐ 23. **Do** Job Sheet 4, "Wire a Three- Phase Motor for Dual Voltages."

☐ 24. **Study** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 25. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 4 repeat Step 23.

☐ 25. **Do** Job Sheet 5, "Perform Maintenance on a Magnetic Contactor."

☐ 26. **Study** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 27. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 5 repeat Step 25.

☐ 27. **Check** With instructor for any additional assignments to be completed.

☐ 28. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 29. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Objective Sheet

Unit Objective

After completing this unit, the student should be able to identify and test or wire common contactors, starters and motors. The student should demonstrate these competencies by completing the assignment sheet and job sheets, and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to motors and controllers with their definitions.
2. List required motor nameplate information.
e. Discuss direct current motor theory of operation.
4. List types of DC motors.
5. Discuss single-phase motor theory of operation.
6. List types of single-phase motors.
7. Discuss three-phase motor theory of operation.
8. List types of three-phase motors.
9. State the procedure for reversing rotation of a three-phase motor.
10. Select from a list of typical supply voltages for three-phase motors.
11. Identify schematics and terminal connections for delta- and wye-wound three-phase motors.
12. Match motor problems with their typical symptoms.
13. Match remedies with the correct symptoms of motor problems.
14. Complete safety rules to observe when working around motors.
15. Identify parts of a magnetic contactor.
16. Select from a list electrical devices or circuits controlled by contactors
17. Identify the parts of a manual motor starter.
18. Name types of motor starters.
19. Identify the parts of magnetic motor starters.
20. List uses of magnetic motor starters.

21. Compare parts in magnetic contactors with parts in magnetic motor starters.

22. Complete statements concerning reasons a contactor cannot be used to control a motor.

23. State purposes of a coil assembly.

24. Identify parts of a coil assembly.

25. Interpret nameplate information. (Assignment Sheet 1)

26. Describe remedies for common motor problems. (Assignment Sheet 2)

27. Use the *National Electrical Code* to answer questions about motor control circuits. (Assignment Sheet 3)

28. Distinguish between motor starters and contactors. (Assignment Sheet 4)

29. Answer questions about uses of contactors and motor starters. (Assignment Sheet 5)

30. Disassemble, inspect, and clean a motor. (Job Sheet 1)

31. Identify run, common, and start terminals on hermetically sealed motors. (Job Sheet 2)

32. Test capacitors with an ohmmeter. (Job Sheet 3)

33. Wire a three-phase motor for dual voltages. (Job Sheet 4)

34. Perform maintenance on a magnetic contactor. (Job Sheet 5)

Information Sheet

Objective 1

Terms and definitions

a. **Arc chute**—Partition between contacts to reduce electrical arcing

b. **Armature**—Portion of coil assembly moved by magnetism

c. **Contactor**—Device used to make or break a motor's power circuit

d. **Delta**—Three-phase circuit in which the windings are connected in series to form a closed loop

e. **Dual voltage motor**—Motor capable of being wired to run at two different voltages

f. **Power factor**—Ratio of active power to apparent power

g. **Relay**—Operated by a change in one electrical circuit to control a device in the same circuit or another circuit; used in control circuits

h. **Shading coil**—Single turn of conducting material mounted on the magnetic assembly face to produce out-of-phase magnetic force

i. **Single phasing**—Loss of one phase of a three-phase system

j. **Starter**—Device used to make and break electrical power circuit

k. **Thermal overload (heater)**—Device used to sense current draw in a circuit and open a control circuit when its rating is exceeded

l. **Torque**—Force that produces a rotating or twisting action

Note: Amount of torque is expressed in foot-pounds.

m. **Wye**—Three-phase circuit in which the windings are connected to form the shape of a "Y" (120 electrical degrees apart)

Objective 2

Required motor nameplate information

a. *NEC* Art 430.7 lists the information required on motor nameplates.

- Manufacturer's name
- Rated voltage
- Full-load amperes
- Rated frequency (Hz)

- If an AC motor, the number of phases
- Rated full-load speed (RPMs)
- Rated ambient temperature
- Time rating (duty rating)
- Rated horsepower if 1/8 hp or more

Objective 3

Direct-current motor theory of operation (DC motors)

Note: Direct-current motors rotate through the interaction of two magnetic fields.

a. A magnetic field is produced at the face of the stationary poles.

b. A magnetic field is produced in the **armature** winding.

c. The fields repel each other causing the **armature** to rotate.

Objective 4

Types of DC motors

a. Shunt motor

Note: A shunt motor has the field winding connected in parallel with its armature.

Application: Blowers, Conveyors, Fans, Printing presses, Pumps, Mixers, most Woodworking tools, and machine tools, etc.

b. Series motors (Sometimes called the universal motor because of its use for both AC and DC voltages).

Note: A series motor has the field windings connected in series with the armature.

Application: Cranes, Hoists, and Hydraulic gauges, Yard locomotives, etc.

c. Compound motor

Note: A compound motor has a combination of series and shunt windings. The series windings are connected in series with the armature and the shunt windings are connected in parallel.

Application: Bulldozers, Punch presses, Shears, etc.

Objective 5

Single-phase motor theory of operation

a. The motor operates on the principle of a single-wave from a two-wire AC system.

b. AC single-phase current produces a varying magnetic field.

Note: When the varying field is applied directly to the windings of most single-phase motors, the motors cannot produce starting torque. Universal motors, because of the series connection of field and armature windings, develop sufficient starting torque.

Objective 6

Types of single-phase motors

Note: Average starting torques of single-phase motors are expressed as percentages of the running torque of each motor.

a. Shaded pole (100% starting torque)

Application: Used in small sizes only for timers, small fans, light duty kitchen-appliances, etc.

b. Split-phase (200% starting torque).

Application: Suited for constant-speed services that require no speed control. Examples include: revolving screens, mixers, conveyors, pumps and compressors, etc. Also suitable for light-starting duty.

c. Capacitor (300% starting torque)

Application: Constant-speed services requiring no speed-control. Heavy-starting duty. Provides better power factors if it is capacitor-start, capacitor-run type. Used in elevators, grinders, refrigerators, etc.

d. Induction-repulsion (400% starting torque)

Application: For constant-speed services with no speed-control for light or heavy starting duty. Used in baking machinery, crushers, flour-mill machinery, etc.

e. Series (500% starting torque)

Application: Controlled-speed services that allow for wide variation between speed and load. Used for heavy intermittent-starting duty or heavy running loads for short periods, and must be directly connected/coupled to load. Loaded at all times or must be in control of operators. Used in cranes, hoists, bailing presses, hydraulic gauges, etc.

Objective 7

Three-phase motor theory of operation

Note: Three-phase motors are the workhorses of industry. They are rugged and reliable and the most dependable type of motor.

a. Current in the stator produces a rotating magnetic field.

b. Currents induced in the rotor create a magnetic field.

c. The rotor turns, seeking an opposite pole.

Objective 8

Types of three-phase motors

Note: An unloaded or lightly loaded three-phase motor will continue to run but will not start under single phase conditions.

a. Squirrel cage induction

Note: This is the most commonly used motor in industrial applications.

b. Wound rotor

Note: This is commonly called a slip-ring motor.

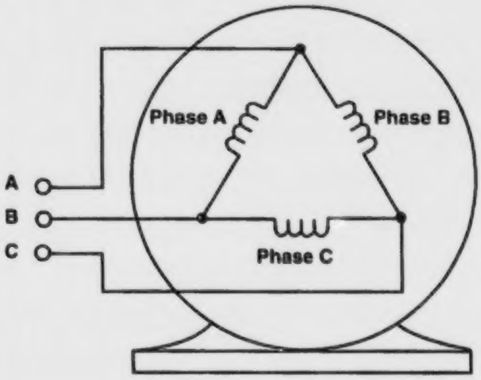
c. Synchronous

Note: Synchronous motors are frequently used for power-factor correction. When used for this purpose, they are known as synchronous condensers.

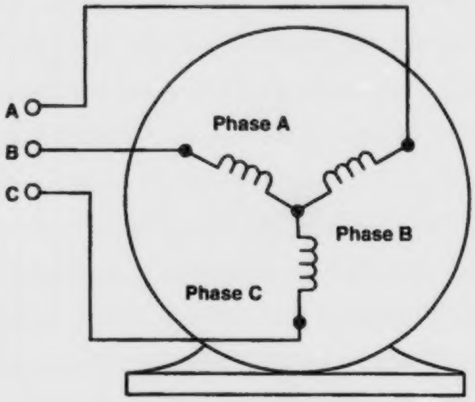
Objective 9

Reversing rotation of three-phase motors—A three-phase motor is reversed by interchanging any two of the three supply lines anywhere between the motor and the source of supply.

Example: Delta-Wound Motor



Example: Wye-Wound Motor (Single Speed)



Objective 10

Typical supply voltages for three-phase motors

a. 240-volt three-phase delta

b. 480-volt three-phase delta

c. 208-volt three-phase wye

d. 480-volt three-phase wye

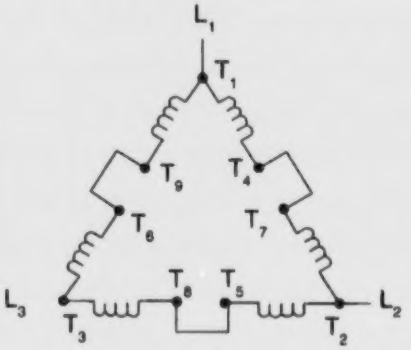
Objective 11

Dual voltage schematics and terminal connections

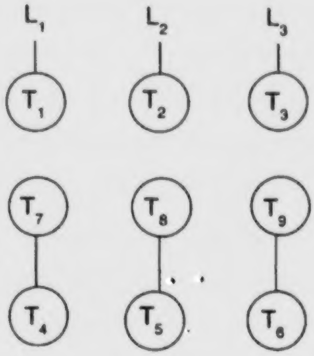
a. Delta-wound nine-lead high voltage motor

Note: On a typical 240/480-volt dual-voltage motor the 240-volt windings would wire in parallel and the 480-volt windings would wire in series, as shown.

Schematic Connection

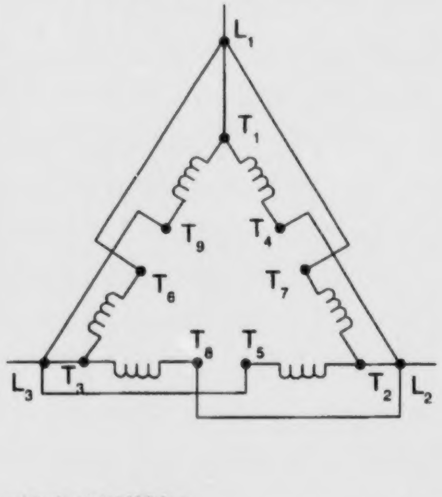

L_1
T_1
T_9
T_4
T_6
T_7
T_8
T_5
L_3
T_3
T_2
L_2

Terminal Connection

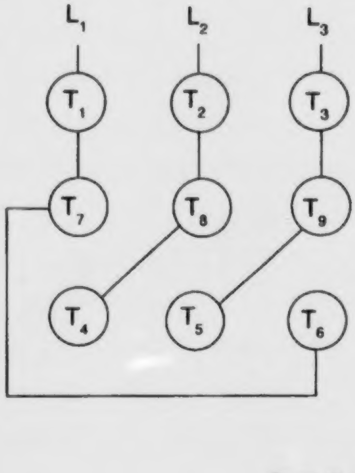

L_1
L_2
L_3
T_1
T_2
T_3
T_7
T_8
T_9
T_4
T_5
T_6

b. Delta-wound nine-lead low voltage motor

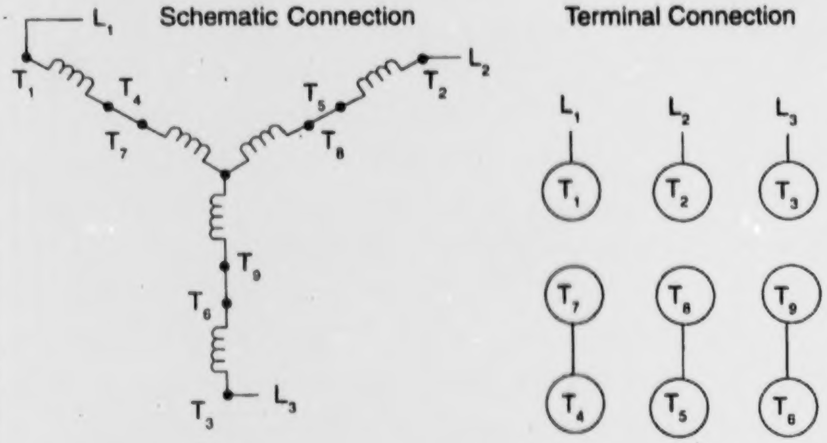
Schematic Connection


L_1
T_1
T_9
T_4
T_6
T_7
T_8
T_5
L_3
T_3
T_2
L_2

Terminal Connection


L_1
L_2
L_3
T_1
T_2
T_3
T_7
T_8
T_9
T_4
T_5
T_6

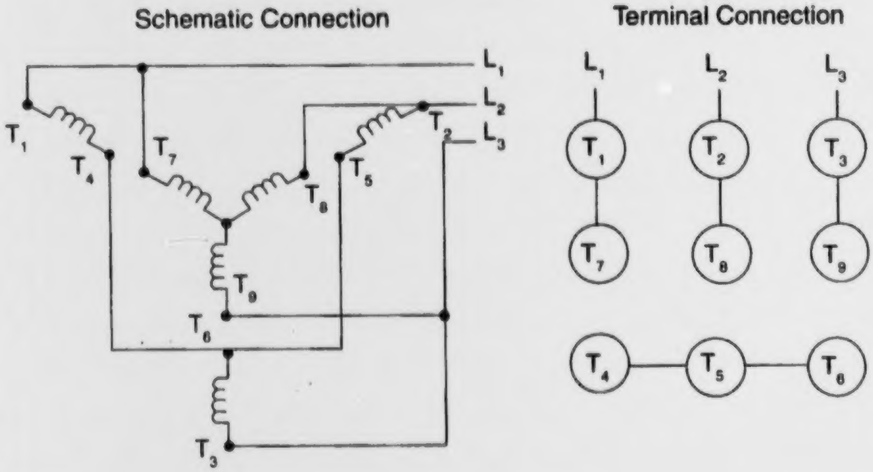
c. Wye-wound nine-lead high voltage motor


Schematic Connection

Terminal Connection

L₁
L₂
L₃
T₁
T₂
T₃
T₄
T₅
T₆
T₇
T₈
T₉

d. Wye-wound nine-lead low voltage motor


Schematic Connection

Terminal Connection

L₁
L₂
L₃
T₁
T₂
T₃
T₄
T₅
T₆
T₇
T₈
T₉

Objective 12

Motor problems and their typical symptoms

a. Failure to start

- Blown fuse or open circuit breaker
- Low voltage or no voltage
- Open wiring circuit
- Incorrect power line connection
- Excessive load
- Excessive end play
- Seized or worn bearings
- Open overload

b. Excessive noise

- Unbalanced parts

  Examples: Bearings, pulley, rotor
- Bent shaft
- Loose parts
- Faulty alignment
- Worn bearings
- Dirt in air gap between rotor and stator
- Uneven air gap
- Shorted silicon-controlled rectifier (SCR) drive unit

c. Overheated bearings

- Lack of oil
- Dirty oil
- Oil not reaching shaft
- Excessive grease or oil
- Excessive belt tension
- Rough bearing surface
- Bent shaft
- Misalignment of shaft and bearing
- Excessive end thrust
- Excessive side pull
- Belt slippage

d. Overheated motor

- Obstruction of ventilating system
- Overloading
- Open overload
- Rotor dragging on stator
- Incorrect voltage
- High ambient temperature
- Lack of oil

Objective 13

Remedies for motor problems

a. Failure to start

- Check supply voltage

  Note: Supply voltage should be within 10 percent of motor nameplate voltage. If no voltage, reset breaker or check fuses.

- Check motor wiring with ohmmeter
- Remove load from motor and try to start
- Move motor shaft by hand to check for end play, side play, and bearing tightness

b. Excessive noise

- Replace out-of-balance pulley
- Remove pulley and check straightness of shaft
- Tighten motor accessories and mounting
- Align drive pulley with driven pulley
- Replace bearings
- Clean motor
- Check for out-of-round motor

c. Overheated bearings

- Use recommended nondetergent motor bearing oil
- Put clean oil in reservoir

  Note: This will be possible only on large motors with bearing oil reservoirs.

- Clean excessive grease buildup from ball bearings
- Adjust belt to proper tension
- Move motor shaft by hand to check for end play, side play, and bearing tightness
- Replace rough or worn bearings
- Remove pulley and check for bent shaft
- Align drive pulley with driven pulley

d. Overheated motor

- Clean motor
- Adjust belt tension
- Check full load amperage
- Check for correct voltage

  Note: A voltage check should be made at the motor terminals with the motor under load.

- Check for loose bearings
- Check for tight bearings
- Check pulley alignment
- Remove pulley and check for bent shaft

Objective 14

Safety rules to observe when working around motors

a. Do not underestimate the danger of the circuit.

b. Use caution around electric arcs.

c. Never install equipment that will overload the circuit.

d. Never bypass protective devices.

e. Protect all wires from physical and thermal hazards.

f. Tag and lock electrical disconnects when working on motors or motor circuits.

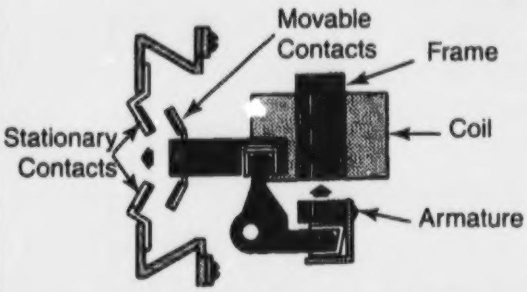
g. Wear eye protection.

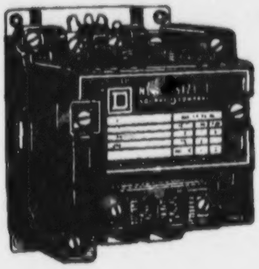
h. Do not touch moving parts.

i. Ground all electric motor frames.

Objective 15

Parts of a magnetic contactor





Adapted with permission of Cutler-Hammer Products/Eaton Corp.; Allen-Bradley, a Rockwell International Company, Milwauke, Wisconsin; and courtesy of Square D Company.

Objective 16

Electrical devices and circuits controlled by magnetic contactors

a. Lighting loads

b. Heaters

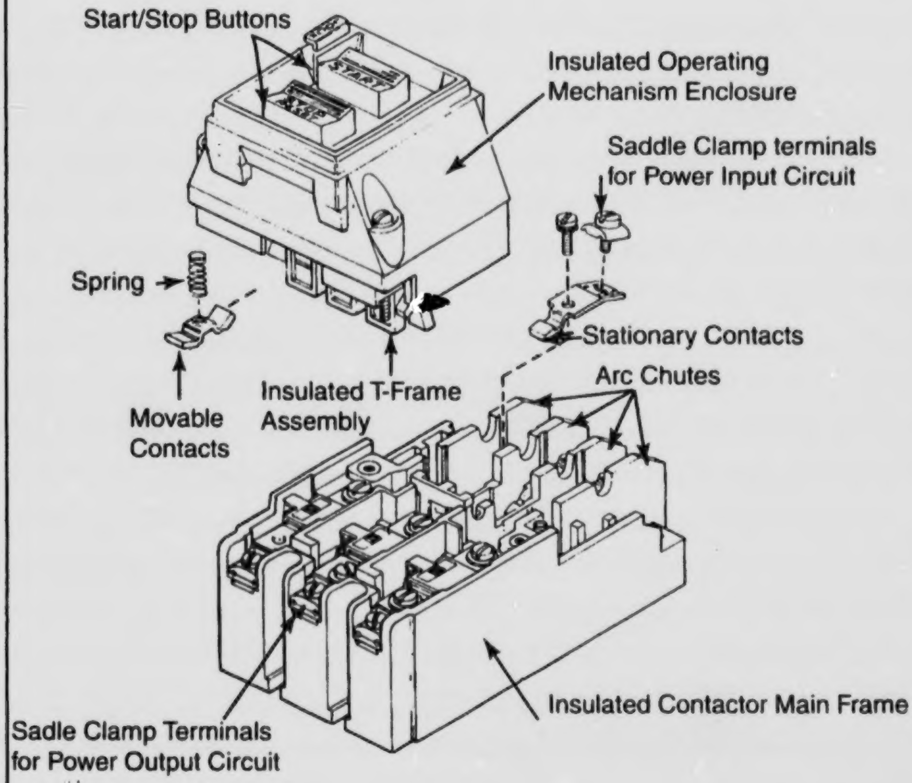
c. Transformers

d. Capacitors

e. Power circuits

Objective 17

Parts of a manual motor starter


Start/Stop Buttons
Insulated Operating Mechanism Enclosure
Saddle Clamp terminals for Power Input Circuit
Spring
Stationary Contacts
Arc Chutes
Insulated T-Frame Assembly
Movable Contacts
Insulated Contactor Main Frame
Sadle Clamp Terminals for Power Output Circuit

Objective 18

Types of motor starters

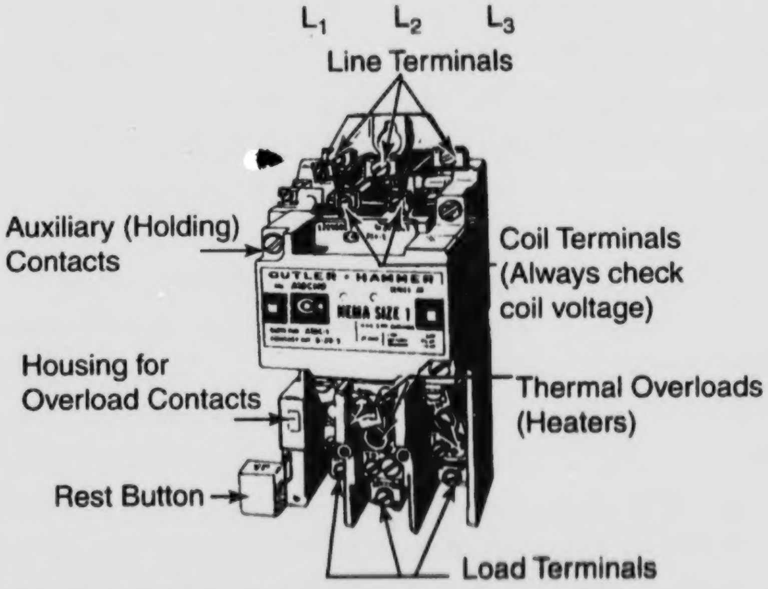
a. Manual

b. Magnetic

Objective 19

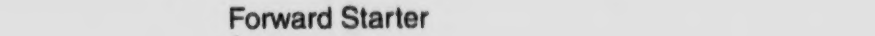
Parts of magnetic motor starters

a. Starting


L_1
L_2
L_3
Line Terminals
Auxiliary (Holding) Contacts
Coil Terminals (Always check coil voltage)
CUTLER - HAMMER
NEMA SIZE 1
Housing for Overload Contacts
Thermal Overloads (Heaters)
Rest Button
Load Terminals

Adapted with permission of Cutler-Hammer Products/Eaton Corporation

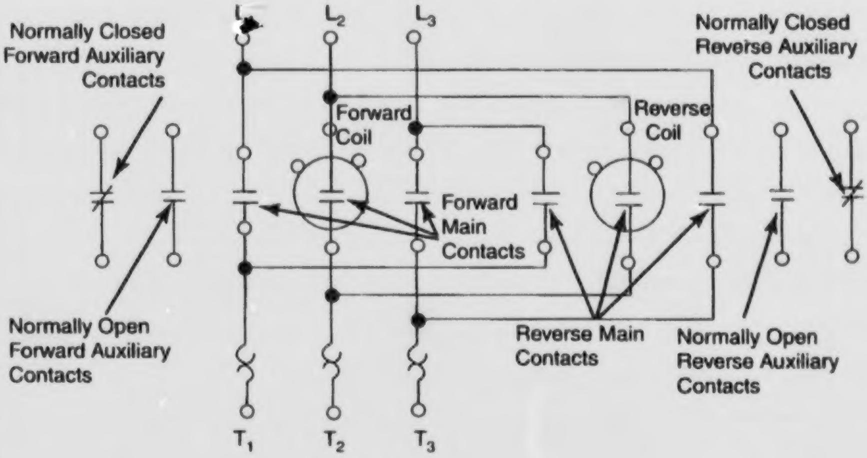
b. Reversing


Forward Starter
CUTLER - HAMMER
NEMA SIZE 1
CUTLER HAMMER
Reverse Starter
Thermal Overloads (Heaters)

Used with permission of Cutler-Hammer Products/Eaton Corporation

Note: Reversing any two phases will change rotation of the motor. In the example, L_1 and L_3 are reversed.

Example:


L
L_2
L_3
Normally Closed Forward Auxiliary Contacts
Normally Closed Reverse Auxiliary Contacts
Forward Coil
Reverse Coil
Forward Main Contacts
Normally Open Forward Auxiliary Contacts
Reverse Main Contacts
Normally Open Reverse Auxiliary Contacts
T_1
T_2
T_3

Objective 20

Uses of magnetic motor starters

a. Starting motors

b. Reversing motors

c. Braking motors to stop

d. Controlling speed of motors

Objective 21

Comparison of parts in magnetic contactors and parts in magnetic motor starters

Note: Motor starters are contactors with overload protection for the motor.

Parts	Contactors	Motor Starters
Line terminals	Yes	Yes
Power contacts	Yes	Yes
Load terminals	Yes	Yes
Holding contacts	Yes	Yes
Coil	Yes	Yes
Thermal overloads (heaters)	No	Yes
Reset button	No	Yes
Overload contact	No	Yes

Objective 22

Reasons a contactor cannot be used to control a motor

a. A contactor does not provide running overload protection for the motor.

b. A contactor is not designed for high inrush current for motor starting.

c. A contactor does not contain a set of overload contacts.

Objective 23

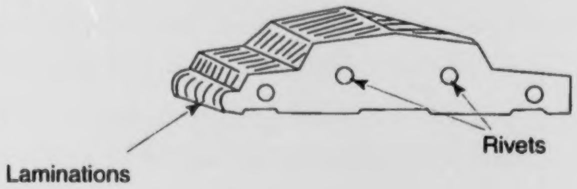
Purposes of a coil assembly

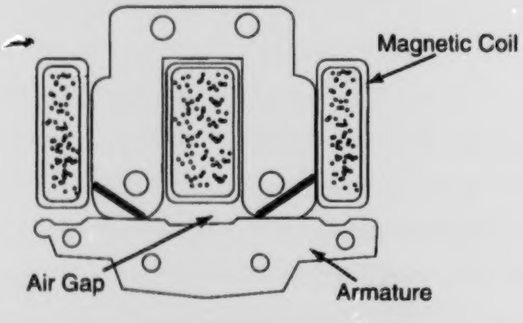
a. To change an electrical signal to a magnetic signal.

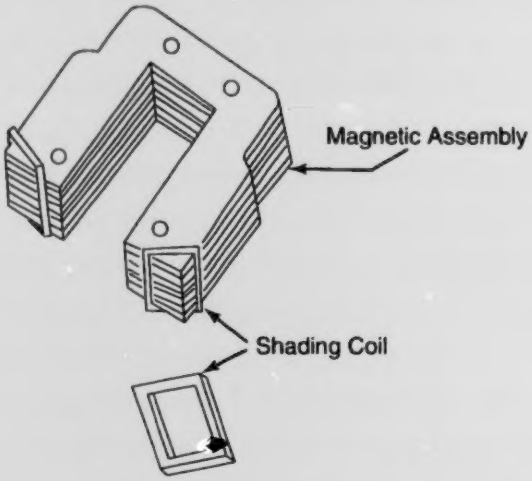
b. To activate the mechanical portion of the motor starter.

Objective 24

Parts of a coil assembly


Rivets
Laminations


Magnetic Coil
Air Gap
Armature


Magnetic Assembly
Shading Coil

Unit Contents

Student Components

Student Page

Learning Activities Sheet 8–3

Objective Sheet 8–5

Information Sheet 8–7

* Assignment Sheets

1—Construct a Basic Ladder Diagram 141
2—Identify Electrical Symbols in a Wiring Diagram 143

* Assignment Sheets are located in Student Workbook 1.

Prerequisites:
None

Learning Activities Sheet

Student Name ____

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 6.

☐ 4. **Do** Assignment Sheet 1, "Construct a Basic Ladder Diagram."

☐ 5. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 6. If the evaluation is not satisfactory, repeat Steps 3 and 4.

☐ 6. **Do** Assignment Sheet 2, "Identify Electrical Symbols in a Wiring Diagram."

☐ 7. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 8. If the evaluation is not satisfactory, repeat Steps 3 and 6.

☐ 8. **Check** With instructor for any additional assignments to be completed.

☐ 9. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 10. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Objective Sheet

Unit Objective

After completing this unit, the student should be able to draw and interpret electrical control diagrams. The student should demonstrate these competencies by completing the assignment sheets, and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to electrical diagrams with their correct definitions.
2. Complete characteristics of wiring diagrams.
3. Select true statements concerning characteristics of ladder diagrams.
4. State the characteristics of one-line diagrams.
5. Identify wiring and ladder diagram symbols.
6. Arrange in order major steps in constructing a ladder diagram.
7. Construct a basic ladder diagram. (Assignment Sheet 1)
8. Identify electrical symbols in a wiring diagram. (Assignment Sheet 2)

Information Sheet

Objective 1

Terms and definitions

a. **Across-the-line**—Method of starting an electric motor by connecting it directly to supply line

b. **Automatic starting**—Pertaining to self-acting starter completely controlled by pilot switches or some other sensing device

c. **Auxiliary contact**—Contact provided in addition to the main circuit contacts but operated with the main contacts

Note: Auxiliary contacts are mechanically operated by the coil of the starter or contactor.

d. **Bimetal**—Two different metals bonded to provide fast heat transfer to trip contacts by mechanical deflection

Note: Bimetals are frequently used in thermal overload relays.

e. **Contactor**—Device without overload protection; repeatedly establishes and interrupts an electric power circuit

f. **Full voltage control**—Function of magnetic control that connects equipment directly to supply line on starting

g. **Jogging (inching)**—Momentarily operating; moving driven machine a small distance

h. **Ladder diagram (line diagram)**—Schematic consisting of symbols and lines that indicate power source and how current flows through various parts of a control circuit

Note: Ladder diagrams depict control logic.

i. **Magnetic contactor**—Contactor operated electromechanically

j. **Multispeed starter**—Starter designed to start motor at a reduced speed and build to full speed in preset steps

k. **One-line diagram**—Schematic consisting of single-phase and three-phase power lines; indicates power distribution, and fuse and interrupter coordination

l. **Overload relay**—Device for protecting motor from overload current or voltage

Note: An overload relay does not necessarily protect against short circuit, but does cause and maintain interruption from power supply until reset.

m. **Push button**—Switch, manually operable plunger, button, or actuating device

n. **Relay**—Electromechanical device operated by a coil; uses contacts to make or break circuits

o. **Remote control**—Device that controls electrical apparatus from some distance

p. **Selector switch**—Manually operated multiposition switch

Note: The selector switch is also called a *multiple-contact switch*.

q. **Starter**— Control device with electric contactor and overload protection; designed to protect motor from voltage inrush during starting

r. **Timer**—Pilot device that delays closing or opening of a circuit for a specific time; may be motor driven, solenoid-actuated, or electric

s. **Wiring diagram**—Consists of symbols and lines that indicate all connections and placement of all component parts in a device or circuit, including the power circuit wiring

Objective 2

Characteristics of wiring diagrams

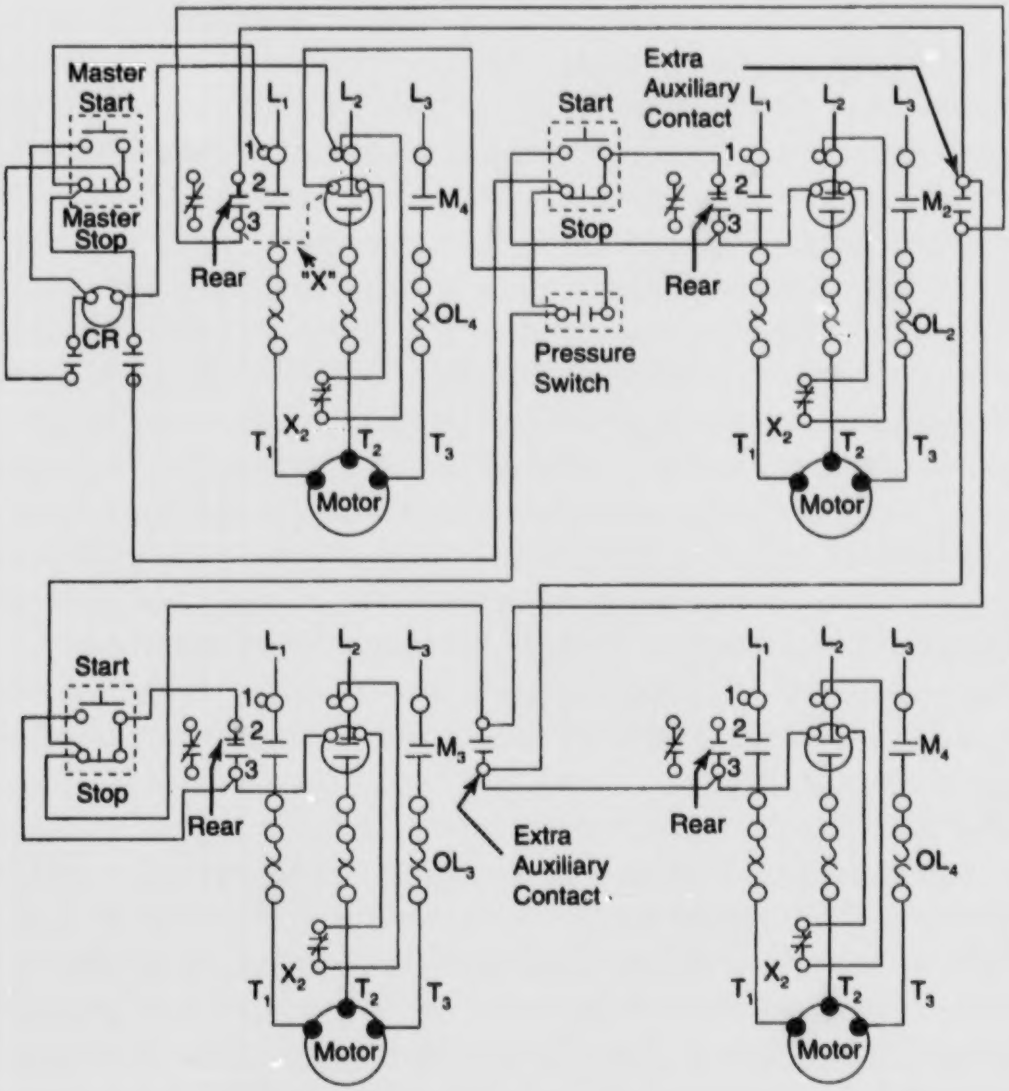
a. They show components in their approximate locations.

b. They provide a guide for field wiring.

c. They use standard electrical symbols.

d. They show power and control lines together.

e. They make circuits difficult to trace.


Master Start
Master Stop
CR
Rear
"X"
L_1
L_2
L_3
1
2
3
M_1
OL_1
X_2
T_1
T_2
T_3
Motor
Start
Stop
Pressure Switch
Extra Auxiliary Contact
M_2
OL_2
M_3
OL_3
M_4
OL_4

Information Sheet

Objective 3

Characteristics of ladder diagrams

Note: The electrical industry is rapidly changing over to ladder diagrams; however, it is important that the electrical technician is able to read and interpret all types of diagrams.

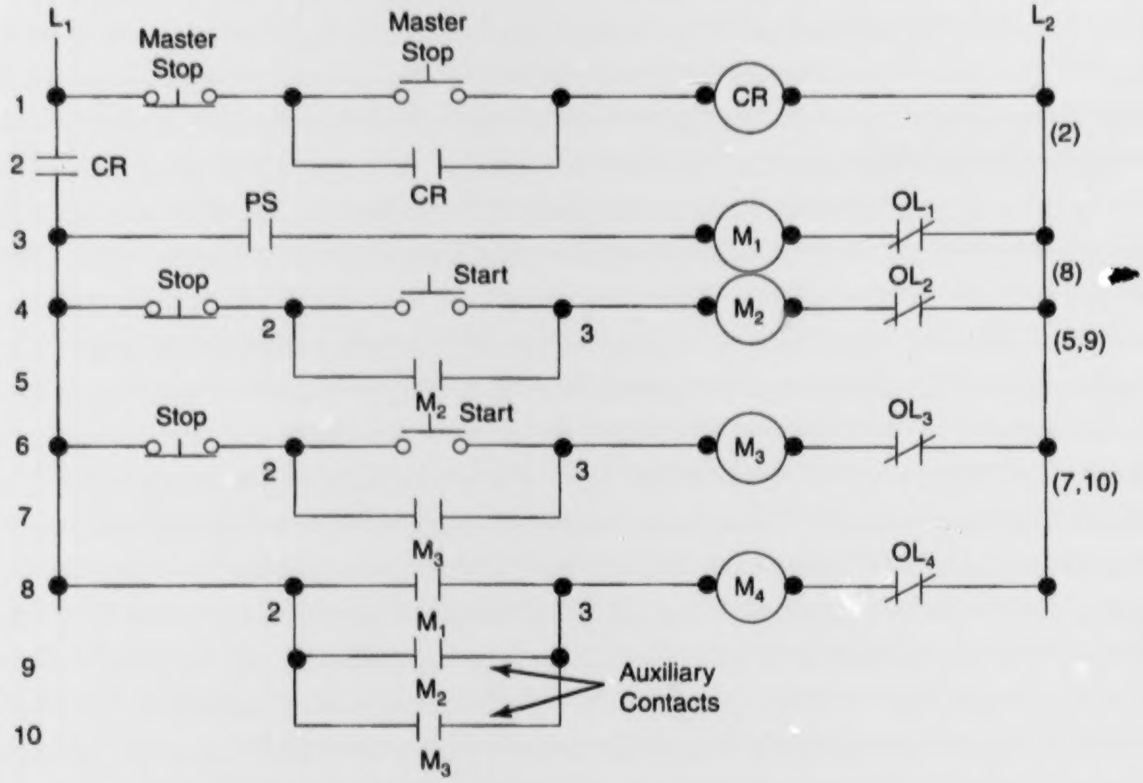
a. They resemble a ladder.

b. They depict individual circuits as ladder rungs.

c. They use standard electrical symbols.

d. They show separate power and control lines.

e. They simplify circuit troubleshooting.


L1
L2
Master Stop
Master Stop
CR
CR
CR
PS
M1
OL1
Stop
Start
M2
OL2
Stop
M2 Start
M3
OL3
M3
M4
OL4
M1
M2
M3
2
3
Auxiliary Contacts
1
2
3
4
5
6
7
8
9
10
(2)
(8)
(5,9)
(7,10)

Objective 4

Characteristics of one-line diagrams

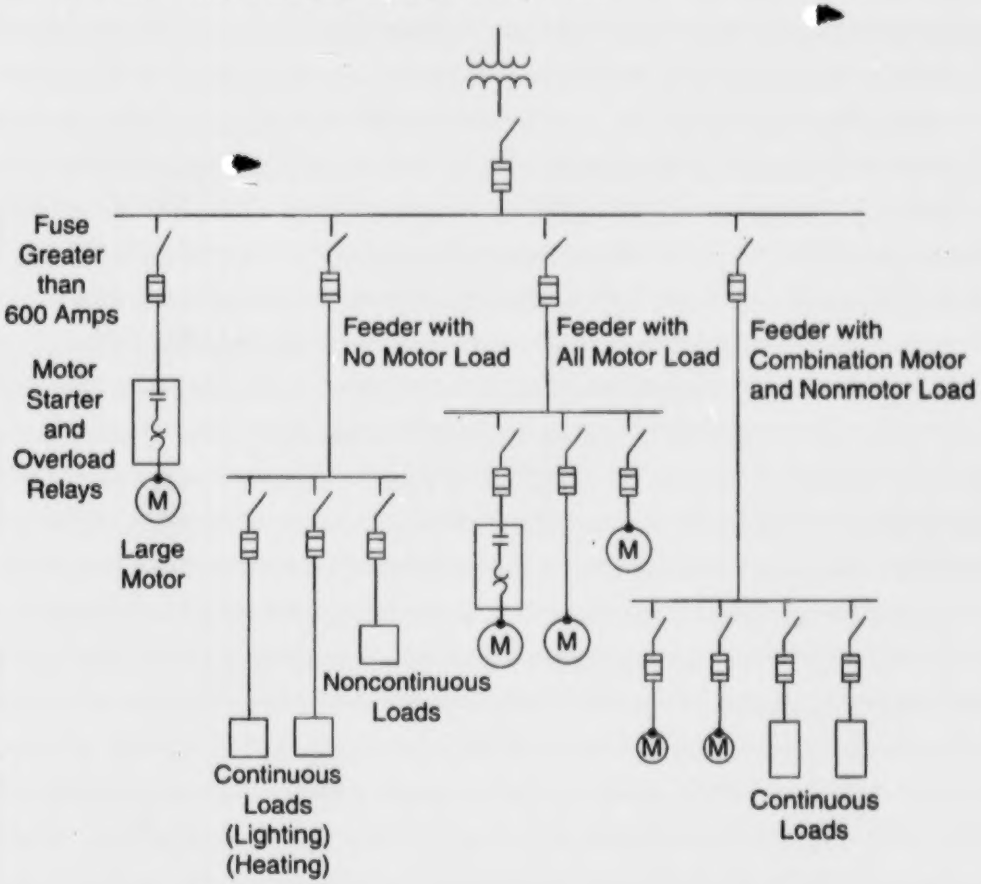
a. They show the location of transformers.

b. They show the location of overcurrent devices.

c. The indicate overcurrent device sizes.

d. They indicate sizes of loads.

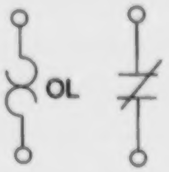
e. They indicate characteristics of loads.


Fuse Greater than 600 Amps
Motor Starter and Overload Relays
M
Large Motor
Feeder with No Motor Load
Feeder with All Motor Load
Feeder with Combination Motor and Nonmotor Load
M
M
M
M
M
Noncontinuous Loads
Continuous Loads (Lighting) (Heating)
Continuous Loads

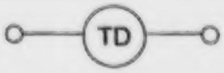
Objective 5

Wiring and ladder diagram symbols

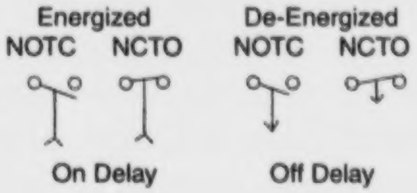
a. Thermal overload relay



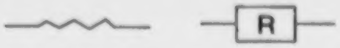
b. Time delay relay coil



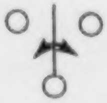
c. Timed contacts


Energized
NOTC
NCTO
De-Energized
NOTC
NCTO
On Delay
Off Delay

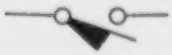
d. Standard resistor



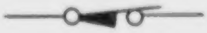
e. Plugging switch



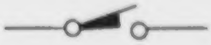
f. Limit switch (normally open)



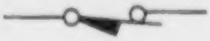
g. Limit switch (normally closed)



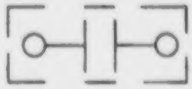
h. Limit switch (held open)



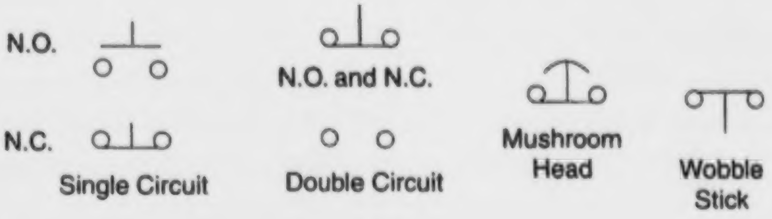
i. Limit switch (held closed)



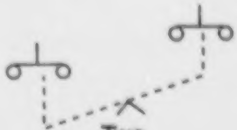
j. Two-wire pilot device

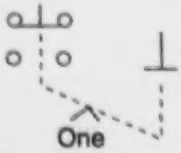


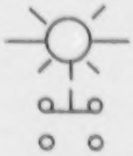
k. Momentary contacts


N.O.
N.O. and N.C.
N.C.
Single Circuit
Double Circuit
Mushroom Head
Wobble Stick

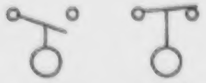
l. Maintained contacts


Two Single Circuit

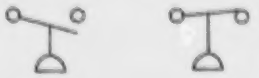

One Double Circuit


Illuminated

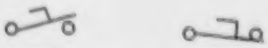
m. Liquid level switch


N.O. N.C.

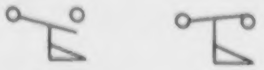
n. Pressure and vacuum switches


N.O. N.C.

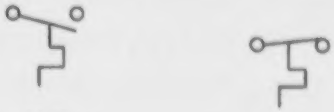
o. Foot switches


N.O. N.C.

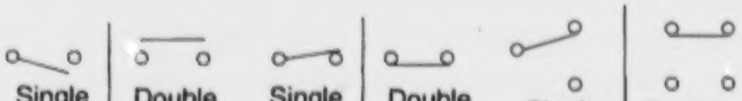
p. Flow switch


N.O. N.C.

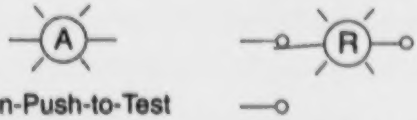
q. Temperature-actuated switch


N.O. N.C.

r. Switches


Single Break
Double Break
SPST N.O.
Single Break
Double Break
SPST N.C.
Single Break
Double Break
SPDT

s. Pilot lights

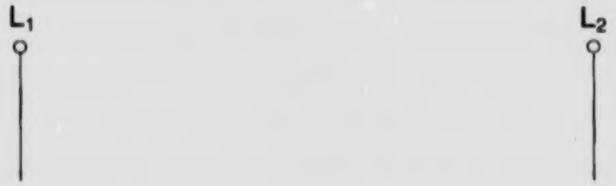


Non-Push-to-Test

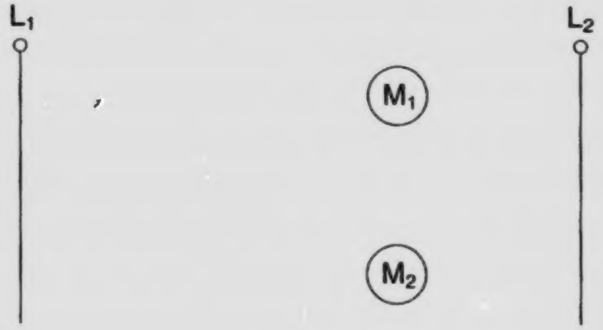
Push-to-Test

Objective 6 **Major steps in constructing ladder diagrams**

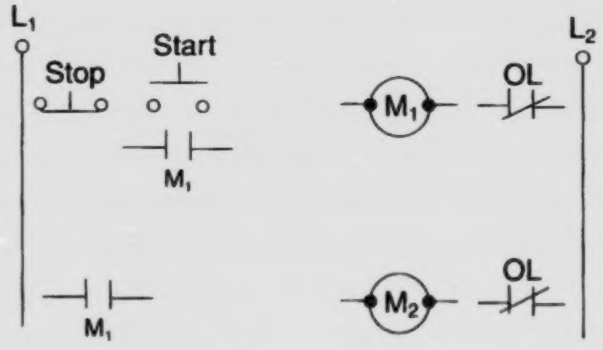
a. Establish and label power lines.



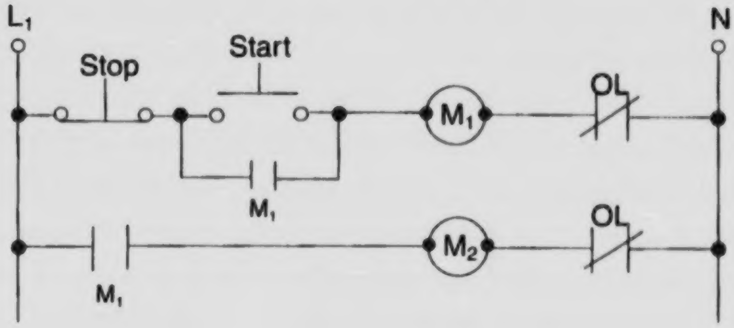
b. Identify and label loads



c. Identify and label control devices and contacts for each circuit (rung).

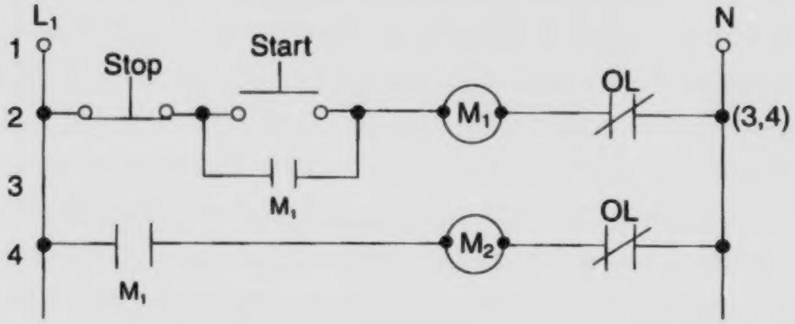

L1
L2
Stop
Start
M1
M1
OL
M1
M2
OL

d. Connect circuit wires, keeping ladder rungs an equal distance apart for ease of reading.


L₁
N
Stop
Start
M₁
OL
M₁
M₂
OL
M₁

e. Number rungs, and cross reference.

Note: This step is extremely important, especially in more complex diagrams containing many rungs.


L₁
N
1
Stop
Start
2
M₁
OL
(3,4)
3
M₁
OL
4
M₂
M₁

Unit Contents

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Information Sheet 9–9

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2—Draw a Ladder Diagram of a Three-Wire Control with an "On" Indicating Pilot Light 147
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4—Determine the Number and Size of Conductors Needed to Operate a Two-Wire Control System 151
5—Determine the Number and Size of Conductors Needed to Operate a Three-Wire Control System 153

* Job Sheets

1—Wire a Two-Wire Control 155
2—Wire Two Float Switches to Operate a Starter (series connection) 159
3—Wire Two Float Switches to Operate a Starter (parallel connections) 163
4—Wire a Pressure Switch to Operate a Starter with "On" and "Off" Pilot Lights 167
5—Wire A Three-Wire Control System 171
6—Wire a Multiple Station Three-Wire Control 175
7—Wire a Multiple Station Three-Wire Control with "On" and "Off" Pilot Lights 179

* Assignment Sheets and Job Sheets are located in Student Workbook 2.

Prerequisites:
None

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 7.

☐ 4. **Do** Assignment Sheet 1, "Complete a Ladder Diagram and a Wiring Diagram of a Two-Wire Control Using a Thermal Switch."

☐ 5. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 6. If the evaluation is not satisfactory, repeat Steps 3 and 4.

☐ 6. **Do** Job Sheet 1, "Wire a Two-Wire Control."

☐ 7. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 8. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat Step 6.

☐ 8. **Do** Assignment Sheet 2, "Draw a Ladder Diagram of a Three-Wire Control with an "On" Indicating Pilot Light."

☐ 9. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 10. If the evaluation is not satisfactory, repeat Steps 3 and 8.

☐ 10. **Do** Assignment Sheet 3, "Draw a Ladder and a Wiring Diagram of a Three-Wire Control with an "Off" Indicating Pilot Light."

☐ 11. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 12. If the evaluation is not satisfactory, repeat Steps 3 and 10.

☐ 12. **Do** Job Sheet 2, "Wire Two Float Switches to Operate a Starter (series connection)."

☐ 13. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 14. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat Step 12.

☐ 14. **Do** Job Sheet 3, "Wire Two Float Switches to Operate a Starter (parallel connections."

☐ 15. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 16. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat Step 14.

☐ 16. **Do** Job Sheet 4, "Wire a Pressure Switch to Operate a Starter with "On" and "Off" Pilot Lights."

☐ 17. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 18. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 4 and repeat Step 16.

☐ 18. **Do** Job Sheet 5, "Wire a Three-Wire Control System."

☐ 19. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 20. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 5 and repeat Step 18.

☐ 20. **Do** Job Sheet 6, "Wire a Multiple Station Three-Wire Control."

☐ 21. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 22. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 6 and repeat Step 20.

☐ 22. **Do** Job Sheet 7, "Wire a Multiple Station Three-Wire Control with "On" and "Off" Pilot Lights."

☐ 23.	**Stop**	Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 24. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 7 and repeat Step 22.
☐ 24.	**Do**	Assignment Sheet 4, "Determine the Number and Size of Conductors Needed to Operate a Two-Wire Control System."
☐ 25.	**Stop**	Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 26. If the evaluation is not satisfactory, repeat Steps 3 and 24.
☐ 26.	**Do**	Assignment Sheet 5, " Determine the Number and Size of Conductors Needed to Operate a Three-Wire Control System."
☐ 27.	**Stop**	Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 28. If the evaluation is not satisfactory, repeat Steps 3 and 26.
☐ 28.	**Check**	With instructor for any additional assignments to be completed.
☐ 29.	**Take**	Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.
☐ 30.	**Stop**	Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Objective Sheet

Unit Objective

After completing this unit, the student should be able to interpret wiring and ladder diagrams related to two-wire and three-wire controls as well as wire these systems. The student should demonstrate these competencies by completing the assignment sheets and job sheets, and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to two- and three-wire controls with their correct definitions.
2. Identify typical two-wire pilot devices.
3. List advantages of two-wire controls.
4. State the basic rule for three-wire controls
5. List advantages of three-wire controls.
6. Describe the operation of a two-wire control system.
7. Describe the operation of a three-wire control system.
8. Complete a ladder and a wiring diagram of a two-wire control using a thermal switch. (Assignment Sheet 1)
9. Draw a ladder diagram of a three-wire control with an "on" indicating pilot light. (Assignment Sheet 2)
10. Draw a ladder and a wiring diagram of a three-wire control with an "off" indicating pilot light. (Assignment Sheet 3)
11. Determine the number and size of conductors needed to operate a two-wire control system. (Assignment Sheet 4)
12. Determine the number and size of conductors needed to operate a three-wire control system. (Assignment Sheet 5)
13. Wire a two-wire control. (Job Sheet 1)
14. Wire two float switches to operate a starter (series connection). (Job Sheet 2)
15. Wire two float switches to operate a starter (parallel connections). (Job Sheet 3)
16. Wire a pressure switch to operate a starter with "on" and "off" pilot lights. (Job Sheet 4)
17. Wire a three-wire control system. (Job Sheet 5)
18. Wire a multiple station three-wire control. (Job Sheet 6)
19. Wire a multiple station three-wire control with "on" and "off" pilot lights. (Job Sheet 7)

Information Sheet

Objective 1

Terms and definitions

a. **Auxiliary contacts**—Set of normally open or normally closed contacts on a starter, contactor, or relay that close or open when main contacts close or open

b. **Indicating pilot light**—Small light that indicates status of controls or machinery

c. **Low voltage protection**—Magnetic control only; nonautomatic restarting; three-wired control; power failure disconnects service; power restored by manual restart

d. **Low voltage release**—Manual and magnetic control; automatic restarting; two wire control; power failure disconnects service; when power is restored the controller automatically restarts motor

e. **Pilot device**—Directs operation of another device; alters the electrical circuit

f. **Three-wire control**—Uses momentary contact; start/stop stations and a memory circuit interlock connected in parallel with the start button to maintain the circuit

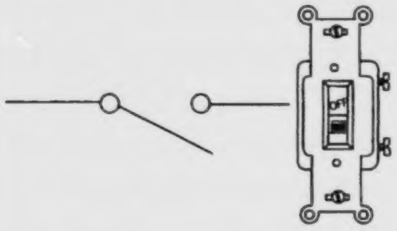
g. **Two-wire control**—Any type of switch having definite "on" and "off" positions that are used to control a magnetic starter or contactor

Objective 2

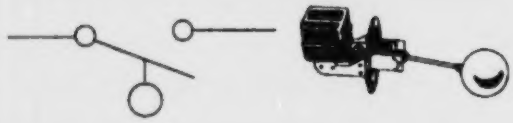
Typical two-wire pilot devices

Note: There are many different pilot devices. These are the most common.

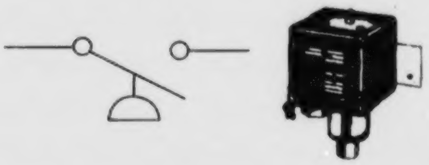
a. Toggle switch



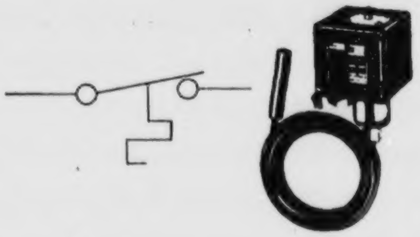
b. Float switch



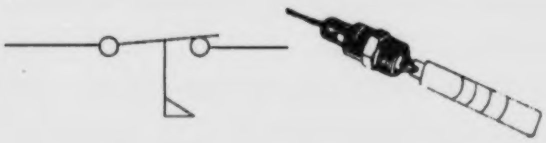
c. Pressure switch



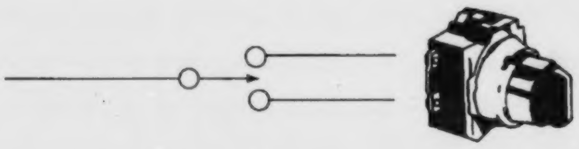
d. Thermal switch



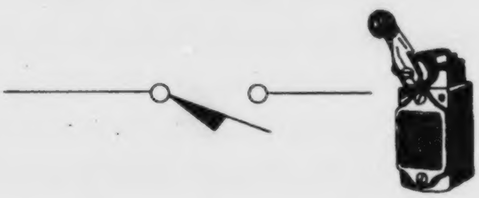
e. Flow switch



f. Selector switch



g. Limit switch



Objective 3

Typical two-wire pilot devices

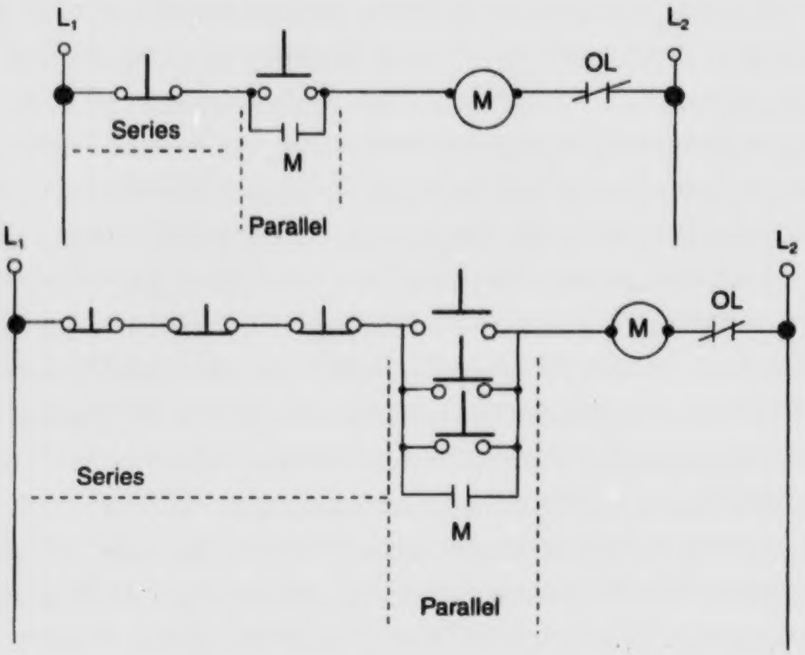
a. Provide low voltage release

b. Do not require a human operator

Objective 4

Basic rule for three-wire controls—Stop buttons are in series with auxiliary contacts and start buttons are in parallel with auxiliary contacts.

Note: This rule will apply no matter how many start/stop stations are used.



Objective 5

Advantages of three-wire controls

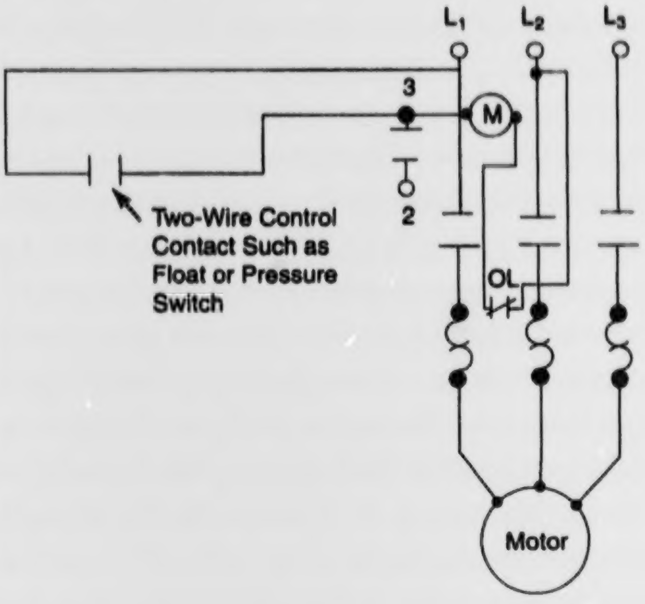
a. Provide low voltage protection

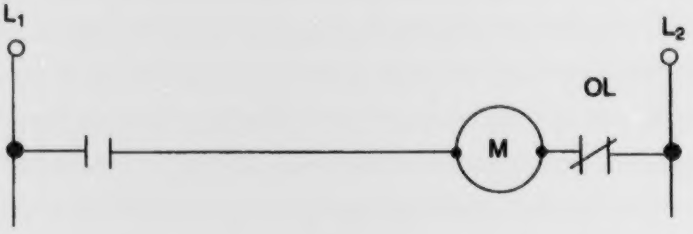
Note: This protects both the operator and the equipment.

b. Allows for easy installation of indicating pilot lights.

Objective 6

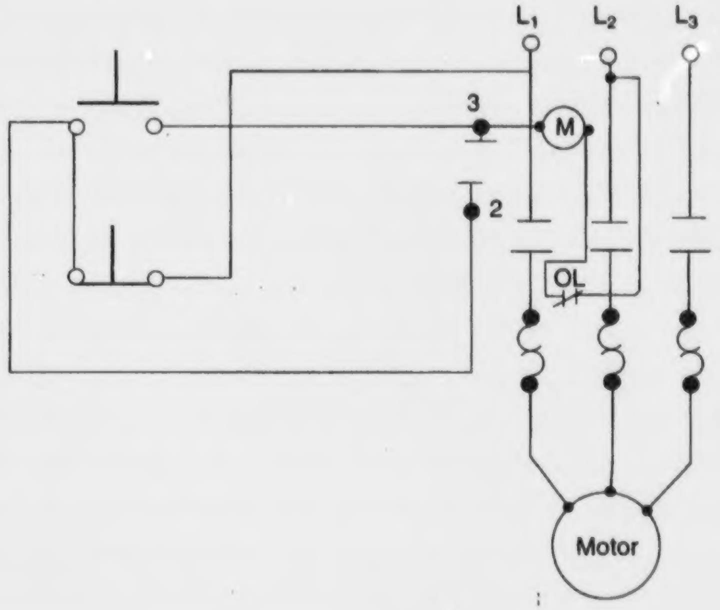
Operation of a two-wire control system—When the two-wire device is closed through some type of mechanical action, it allows current to flow to the starter's coil, energizing the coil and causing the starter to close.

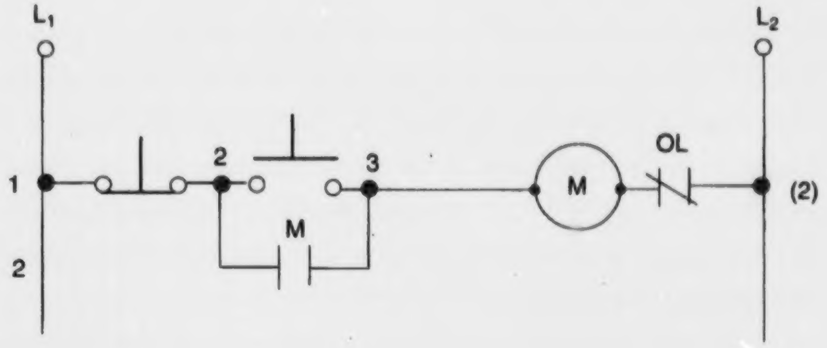

L1
L2
L3
3
M
2
OL
Two-Wire Control Contact Such as Float or Pressure Switch
Motor



Objective 7

Operation of a three-wire control system—When the start button is depressed, current is allowed to flow to the magnetic coil, energizing the coil. When the coil energizes the magnetic field, it pulls the armature toward it, closing the main contacts. As the armature closes, it also mechanically closes the auxiliary contacts (memory contacts), giving the current a path around the start button and keeping the coil energized. When the stop button is depressed, the flow of current is interrupted, allowing the magnetic field to dissipate.





Unit Contents

Student Components

Student Page

Learning Activities Sheet 10–3

Objective Sheet 10–5

Information Sheet 10–7

* Assignment Sheets

1—Read and Interpret Ladder Diagrams Using Separate Control Circuits 183
2—Answer Questions About Control Circuits 187
3—Determine the Size and Number of Conductors Needed to Operate a Separate Control Circuit 189

* Job Sheets

1—Wire a Relay and a Load with a Separate Control Circuit 191
2—Wire a Three-Phase Starter to Operate by a Separate Control Circuit 195

* Assignment Sheets and Job Sheets are located in Student Workbook 2.

Prerequisites:
None

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 6.

☐ 4. **Do** Assignment Sheet 1, "Read and Interpret Ladder Diagrams Using Separate Control Circuits."

☐ 5. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 6. If the evaluation is not satisfactory, repeat Steps 3 and 4.

☐ 6. **Do** Assignment Sheet 2, "Answer Questions About Control Circuits."

☐ 7. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 8. If the evaluation is not satisfactory, repeat Steps 3 and 6.

☐ 8. **Do** Assignment Sheet 3, "Determine the Size and Number of Conductors Needed to Operate a Separate Control Circuit."

☐ 9. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 10. If the evaluation is not satisfactory, repeat Steps 3 and 8.

☐ 10. **Do** Job Sheet 1, "Wire a Relay and a Load with a Separate Control Circuit."

☐ 11. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 12. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat Step 10.

☐ 12. **Do** Job Sheet 2, "Wire a Three-Phase Starter to Operate by a Separate Control Circuit."

Learning Activities Sheet

☐ 13.	**Stop**	Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 14. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat Step 12.
☐ 14.	**Check**	With instructor for any additional assignments to be completed.
☐ 15.	**Take**	Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.
☐ 16.	**Stop**	Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Objective Sheet

Unit Objective

After completing this unit, the student should be able to read and interpret diagrams and wire separate control circuits. The student should demonstrate these competencies by completing the assignment sheets and job sheets, and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

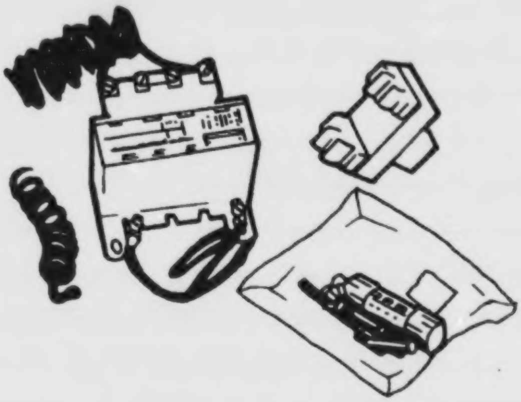
1. Match terms related to separate control circuits with their correct definitions.
2. List reasons for separate control circuits.
3. List applications for separate control circuits.
4. List sources of separate control circuits.
5. Match voltage ratings with their typical control transformer schematics.
6. Describe the necessary changes that must be made to a starter when using a separate control circuit.
7. Read and interpret ladder diagrams using separate control circuits. (Assignment Sheet 1)
8. Answer questions about control circuits. (Assignment Sheet 2)
9. Determine the size and number of conductors needed to operate a separate control circuit. (Assignment Sheet 3)
10. Wire a relay and a load with a separate control circuit. (Job Sheet 1)
11. Wire a three-phase starter to operate by a separate control circuit. (Job Sheet 2)

Information Sheet

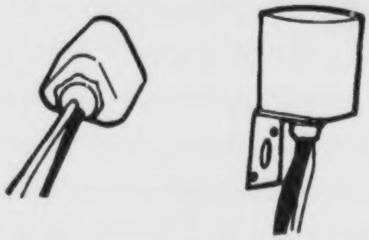
Objective 1

Terms and definitions

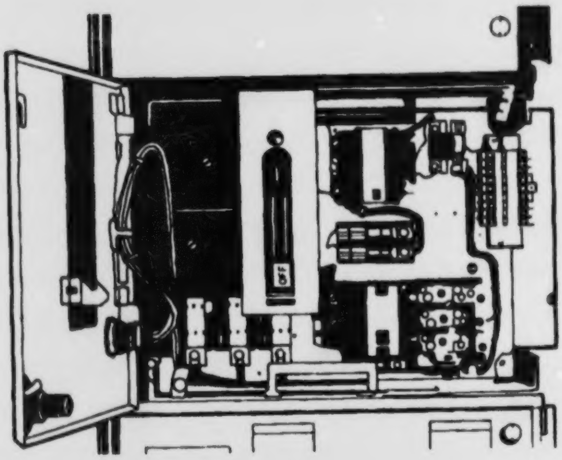
a. **Control transformer**—Small transformer used to step supply voltage down to appropriate control voltage



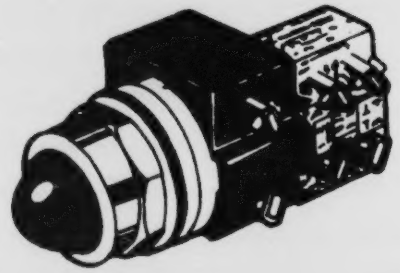
b. **Lightning arrestor**—Device connected to the supply side of a system, designed to absorb transient surges

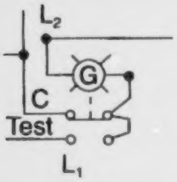


c. **Motor control center**—Large panel used in industrial applications to centrally locate motor starters, motor branch circuit short circuit and ground fault protective devices, and motor branch circuit disconnecting means



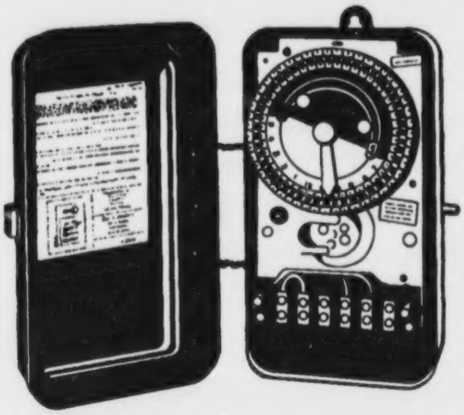
d. **Push-to-test pilot light**—Used to indicate "on" and "off" status of a motor and to verify conditions by means of indicating a burned out lamp



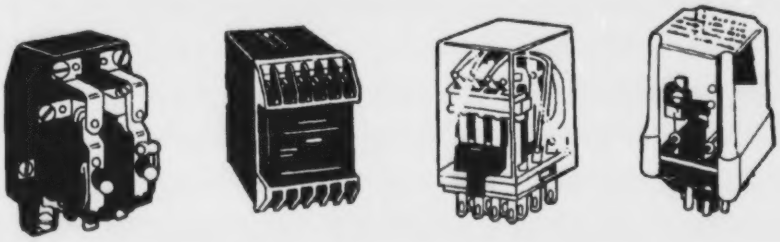


e. **Time clock**—An electromechanical or electronic switch designed to control electrical circuits and equipment based on preset times of day

Note: There are many different types of time clocks. It is necessary to obtain the manufacturer's schematic to wire each type.



f. **Under voltage relay**—Relay whose coils are connected between the line terminals of a motor branch circuit; opens a set of N/O contacts if one or more phases is lost



Objective 2

Reasons for separate control circuits

Note: At times it may become necessary to operate pilot devices or push buttons at a lower voltage than the motor voltage. In such a case, a separate source, such as an isolating transformer or an independent voltage source may be used.

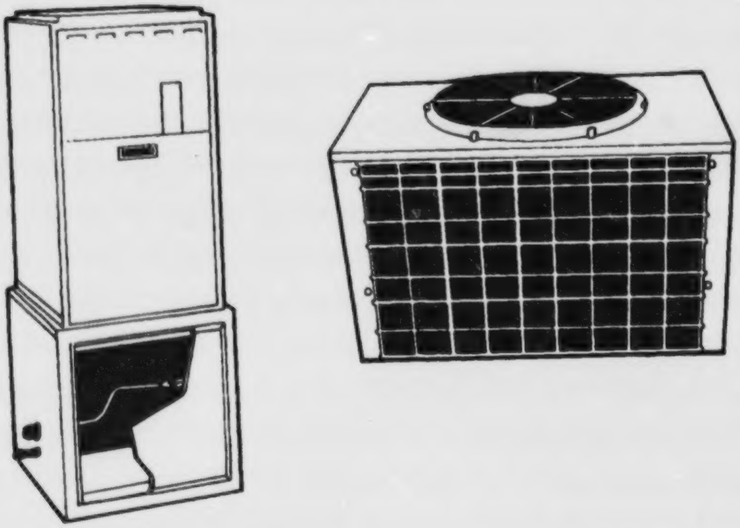
a. To step control voltage down to safe levels

b. To match control voltage with control components' operating voltage

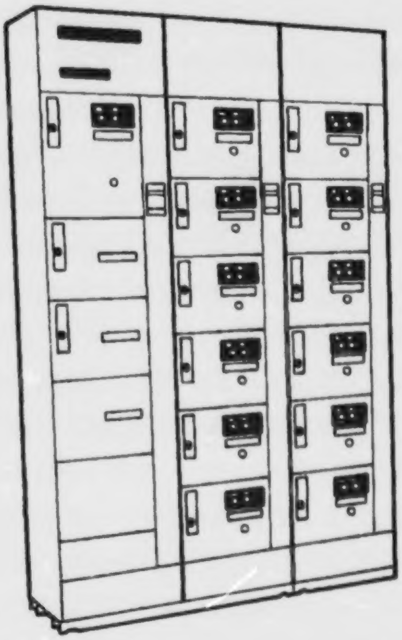
Objective 3

Applications for separate control circuits

a. Air conditioning and heating equipment



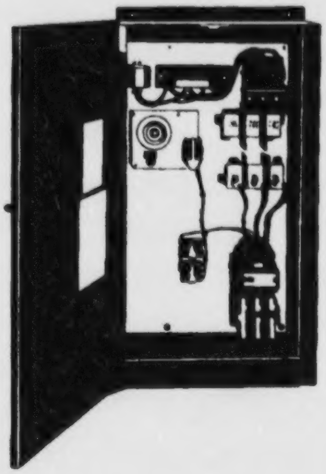
b. Motor control centers



430

c. Pump control panels

Note: These units are extensively used in irrigation systems and oil field applications.



Objective 4

Sources of separate control circuits

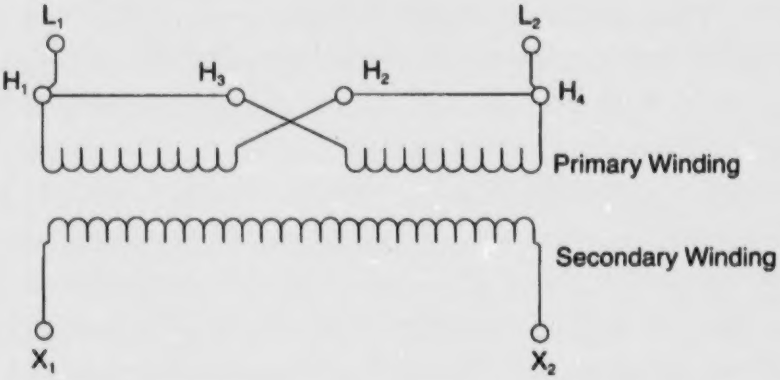
a. Control transformer

b. Separate 120 volt control with circuit disconnect

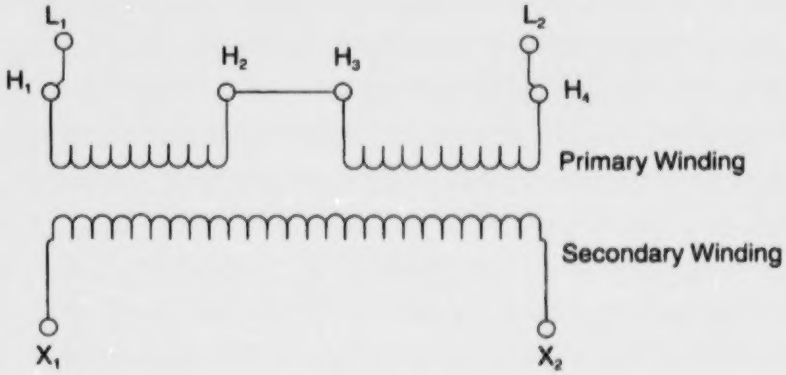
Objective 5

Typical control transformer schematics and their voltage ratings

a. 240 primary; 120 secondary

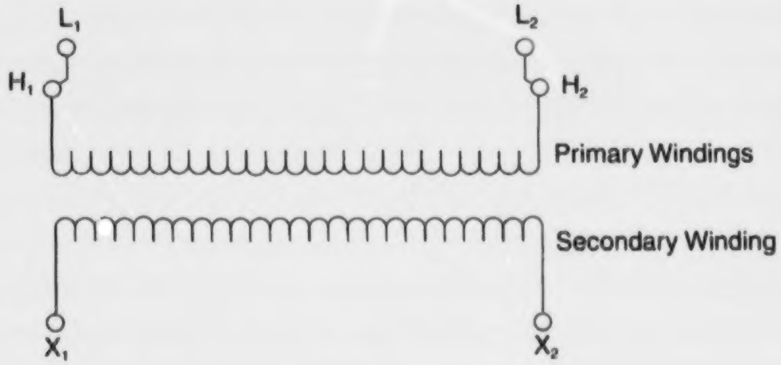

L_1
L_2
H_1
H_3
H_2
H_4
Primary Winding
Secondary Winding
X_1
X_2

b. 480 primary; 120 secondary


L_1
L_2
H_1
H_2
H_3
H_4
Primary Winding
Secondary Winding
X_1
X_2

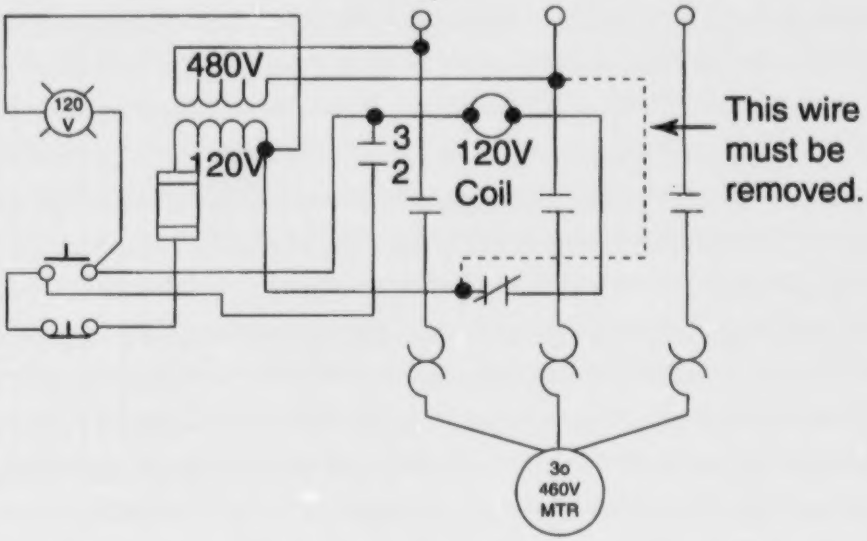
Note: It is important to connect the primary taps correctly to match the input voltage.

c. 240 primary; 24 secondary


L_1
L_2
H_1
H_2
Primary Windings
Secondary Winding
X_1
X_2

Objective 6

Necessary changes that must be made to a starter when using a separate control circuit—When operating three-phase starters on a separate control source, it is necessary to remove all wires that connect from the line terminals to any portion of the control circuitry. Specifically, the wire connected from L_2 to the coil must be removed.


L1
L2
L3
480V
120 V
120V
3
2
120V
Coil
This wire must be removed.
3ϕ
460V
MTR

Unit Contents

Student Components

Student Page

Learning Activities Sheet 11–3

Objective Sheet 11–5

Information Sheet 11–7

* Assignment Sheets

1—Answer Questions Related to a Sequence Control Diagram . . . 199
2—Answer Questions Related to an Auxiliary Contact Interlocking Diagram 201

* Job Sheets

1—Wire Two Starters in Sequence 203
2—Wire Two Starters with Auxiliary Contact Interlocking 207

* Assignment Sheets and Job Sheets are located in Student Workbook 2.

Prerequisites:
None

Learning Activities Sheet

Student Name ____

Place a checkmark in the appropriate box as you complete each of the steps below.

☐	1.	**Take**	Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.
☐	2.	**Read**	Objective Sheet
☐	3.	**Study**	Information Sheet, Objectives 1 through 4.
☐	4.	**Do**	Assignment Sheet 1, "Answer Questions Related to a Sequence Control Diagram."
☐	5.	**Stop**	Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 6. If the evaluation is not satisfactory, repeat Steps 3 and 4.
☐	6.	**Do**	Job Sheet 1, "Wire Two Starters in Sequence."
☐	7.	**Stop**	Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 8. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat Step 6.
☐	8.	**Study**	Information Sheet, Objectives 5 through 7.
☐	9.	**Do**	Assignment Sheet 2, "Answer Questions Related to an Auxiliary Contact Interlocking Diagram."
☐	10.	**Stop**	Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 11. If the evaluation is not satisfactory, repeat Steps 8 and 9.
☐	11.	**Do**	Job Sheet 2, "Wire Two Starters with Auxiliary Contact Interlocking."

☐ 12.	**Stop**	Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 13. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat Step 11.
☐ 13.	**Check**	With instructor for any additional assignments to be completed.
☐ 14.	**Take**	Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.
☐ 15.	**Stop**	Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Objective Sheet

Unit Objective

After completing this unit, the student should be able to read and interpret ladder diagrams dealing with sequence control and auxiliary contact interlocking and wire these types of applications. The student should demonstrate these competencies by completing the assignment sheets and job sheets, and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to sequence control.
2. State the purpose of sequence control.
3. List advantages of sequence control.
4. List uses of sequence control.
5. State the purpose of auxiliary contact interlocking.
6. List advantages of auxiliary contact interlocking.
7. List uses of auxiliary contact interlocking.
8. Answer questions related to a sequence control diagram. (Assignment Sheet 1)
9. Answer questions related to an auxiliary contact interlocking diagram. (Assignment Sheet 2)
10. Wire two starters in sequence. (Job Sheet 1)
11. Wire two starters with auxiliary contact interlocking. (Job Sheet 2)

Information Sheet

Objective 1

Terms and definitions

a. **Auxiliary contacts**—Contacts of a switching device in addition to the main circuit contacts; auxiliary contacts operate with the movement of the main contacts; can be N/O or N/C

Note: In most cases, the addition of auxiliary contacts is a simple stack-on and screw-down procedure.

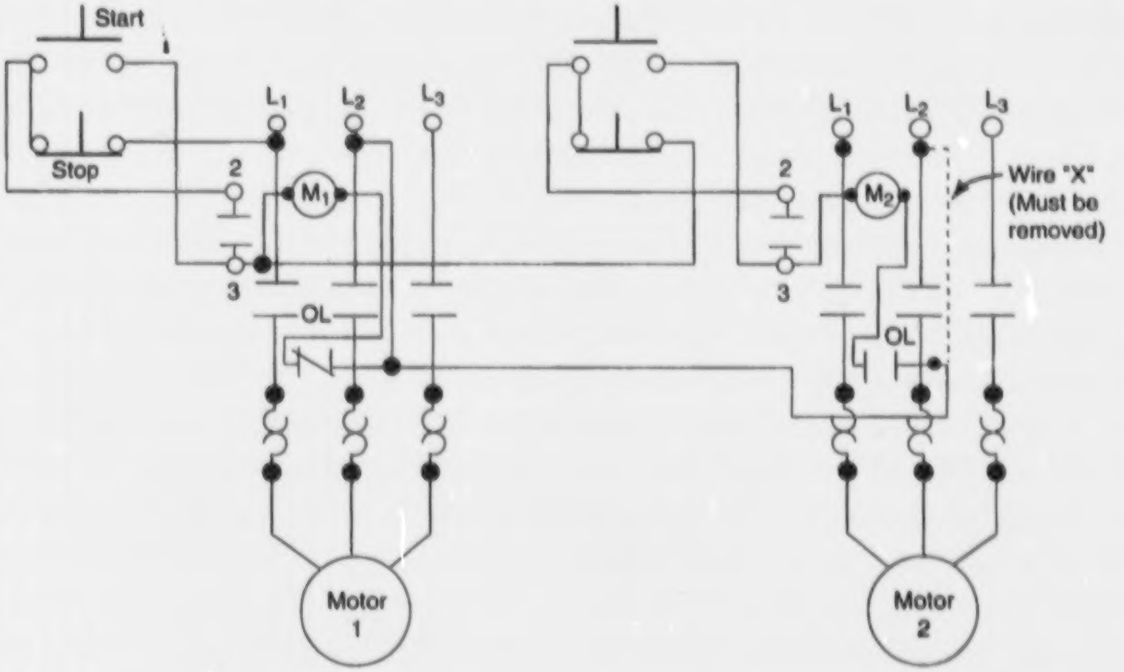
b. **Phase to Phase**—Unintentional contact of two or more electrical phases; results in a short circuit

c. **Down stream**—Coming after; following other devices or events

d. **Interlocking**—Interrelating with other controllers; a device is connected in such a way that the operation of one part controls the operation of another

Objective 2

Purpose of sequence control—To assure that motor 1 is running before motor 2 can operate



Note: The wiring diagram indicates all control circuitry originating from starter one. Remember, starters are pre-wired from L2 through the overloads to the coil. Wire "X" must be removed in order to avoid the possibility of cross phasing.

Objective 3

Advantages of sequence control

a. Assures proper order of start-up

b. Shuts down all "down-stream" motors when a starter fails due to overload

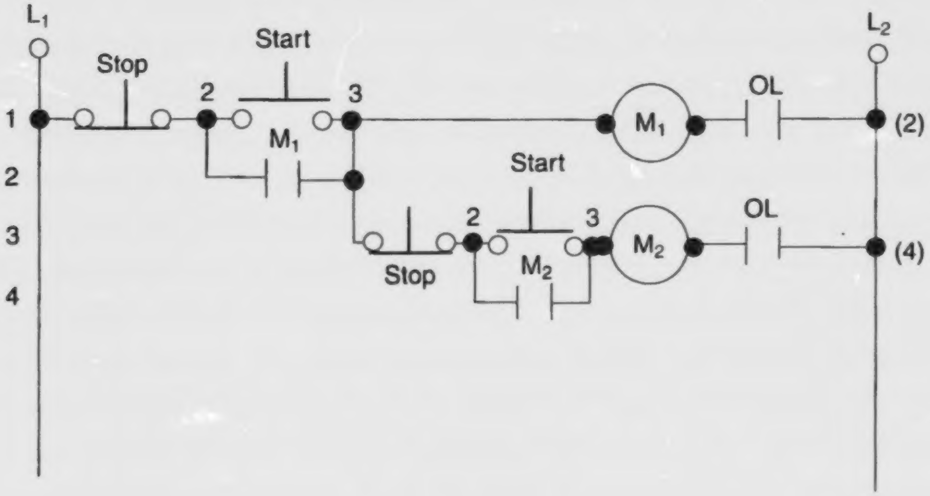
Objective 4

Uses of sequence control

a. Main or subassembly line conveyors

b. Auxiliary equipment associated with machines

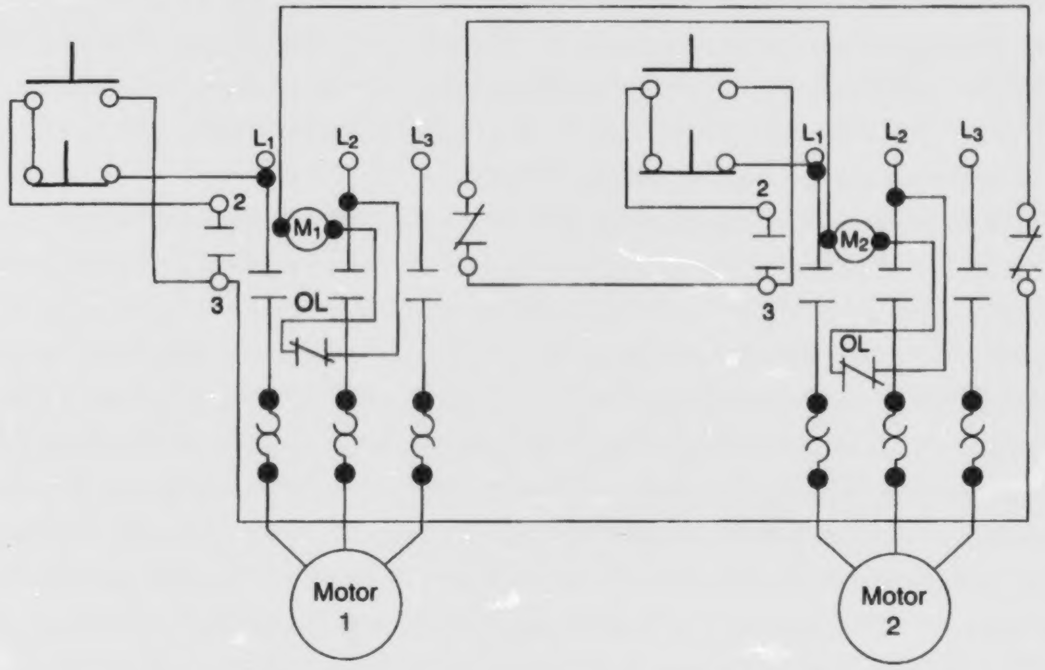
Examples: High pressure lubricating pumps and hydraulic pumps



Note: Tracing out the ladder diagram, you will note that the first starter is wired in the normal configuration of a three-wire control. Then on rung three you will see the second starter's control circuit originated from terminal three on the first starter's auxiliary contacts. This allows for control current to flow to the second starter only after starter one seals in. If the OL of starter one opens, both motors will stop, because coil M_1, will de-energize, opening the contacts on rung two.

Objective 5

Purpose of auxiliary contact interlocking—To prevent two machines or starters from conflicting with one another


L1
L2
L3
2
3
M1
OL
M2
Motor 1
Motor 2

Objective 6

Advantages of auxiliary contact interlocking

a. Prevents motor starters from being energized when not desired

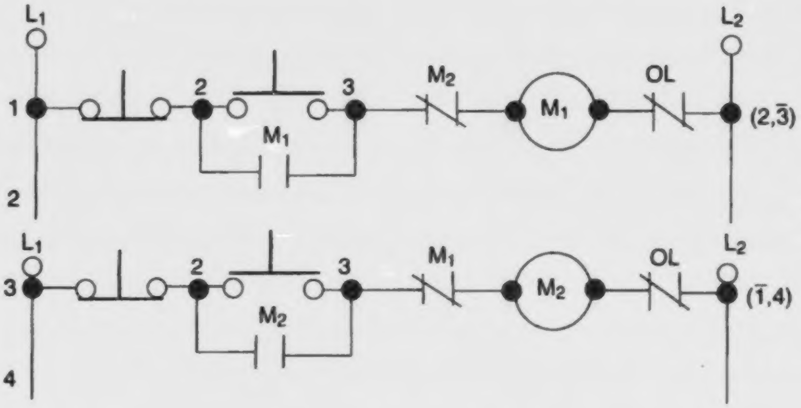
b. Allows another method of sequencing motor starters

Objective 7

Uses of auxiliary contact interlocking

a. Reversing starters

b. Machine tools


L1
L2
1
2
3
M2
M1
OL
(2,3̄)
L1
L2
3
4
2
3
M1
M2
OL
(1̄,4)

Unit Contents

Student Components

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1—Convert Ladder Diagrams to Wring Diagrams 211
2—Determine the Number of Conductors Needed to Operate Jogging Controls 213

* Job Sheets

1—Wire a Job Through a Lock-Stop Push Button 215
2—Wire a Job Through a Two-Position Selector Switch 219
3—Wire a Job Through a Two-Circuit Push Button 223
4—Wire a Job Through a Control Relay 227

* Assignment Sheets and Job Sheets are located in Student Workbook 2.

Prerequisites:
None

Learning Activities Sheet

Student Name ____

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 4.

☐ 4. **Do** Assignment Sheet 1, "Convert Ladder Diagrams to Wiring Diagrams."

☐ 5. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 6. If the evaluation is not satisfactory, repeat Steps 3 and 4.

☐ 6. **Do** Assignment Sheet 2, "Determine the Number of Conductors Needed to Operate Jogging Controls."

☐ 7. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 8. If the evaluation is not satisfactory, repeat Steps 3 and 6.

☐ 8. **Do** Job Sheet 1, "Wire a Jog Through a Lock-Stop Push Button."

☐ 9. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 10. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat Step 8.

☐ 10. **Do** Job Sheet 2, "Wire a Jog Through A Two-Position Selector Switch."

☐ 11. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 12. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat Step 10.

☐ 12. **Do** Job Sheet 3, "Wire a Jog Through a Two-Circuit Push Button."

☐ 13. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 14. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat Step 12.

☐ 14. **Do** Job Sheet 4, "Wire a Job Through a Control Relay."

☐ 15. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 16. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 4 and repeat Step 14.

☐ 16. **Check** With instructor for any additional assignments to be completed.

☐ 17. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 18. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Unit 12 Jogging Controls

Objective Sheet

Unit Objective

After completing this unit, the student should be able to read and interpret ladder diagrams dealing with jogging controls as well as wire these types of circuits. The student should demonstrate these competencies by completing the assignment sheets and job sheets, and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Define the term jogging.
2. Identify methods of jogging control.
3. Match methods of jogging control with their advantages.
4. Describe the sequence of operation of ladder diagrams.
5. Convert ladder diagrams to wiring diagrams. (Assignment Sheet 1)
6. Determine the number of conductors needed to operate jogging controls. (Assignment Sheet 2)
7. Wire a jog through a lock-stop push button. (Job Sheet 1)
8. Wire a jog through a two-position selector switch. (Job Sheet 2)
9. Wire a jog through a two-circuit push button. (Job Sheet 3)
10. Wire a jog through a control relay. (Job Sheet 4)

Information Sheet

Objective 1

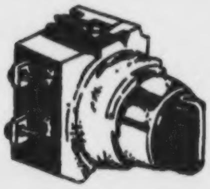
Jogging—The quickly repeated closure of a circuit to start a motor from rest for the purpose of accomplishing small movements

Example: Short movement of a turret lathe in order to load material into the chuck.

Objective 2

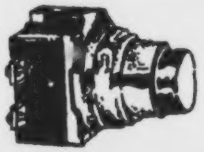
Methods of jogging control

a. Two-position selector switch



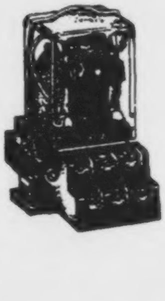
b. Lock-stop push button

c. Two-circuit push button



Note: This is a momentary push button with a two-circuit NC/NO contact block.

d. Control relay



Information Sheet

Objective 3

Advantages of jogging control methods

a. Two position selector switch
  - Inexpensive
  - Easy to install or retrofit
  - Reliable

b. Lock-stop push button
  - Inexpensive
  - Easy to install or retrofit
  - Reliable

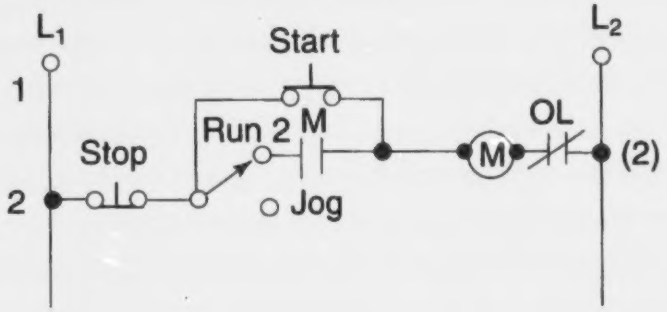
c. Two circuit push button
  - Easy to operate
  - Easy to install on initial wiring

d. Control relay
  - Extremely reliable
  - May be used on multiple starters

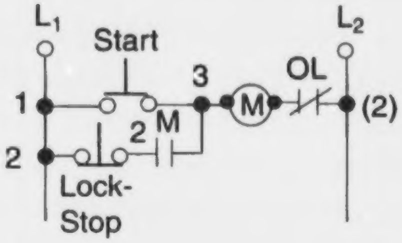
Objective 4

Sequence of operations

a. Two-position selector switch—When switch is in the run position the circuit operates as a normal three-wire control. When switch is in the jog position the memory circuit will no longer operate, thus allowing the start button to "change" to a jog button.

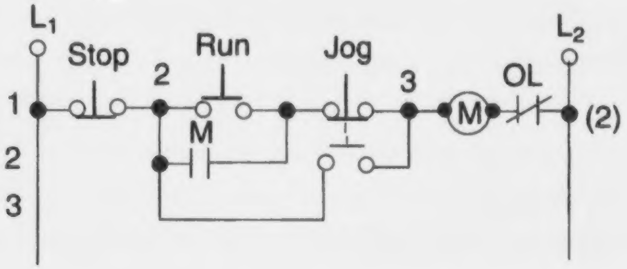


b. Lock-stop push button—When the lock-stop is in the closed position, the circuit operates as a normal three-wire control. When the lock-stop is locked open, it allows the start button to function as a jog, due to the open memory circuit.

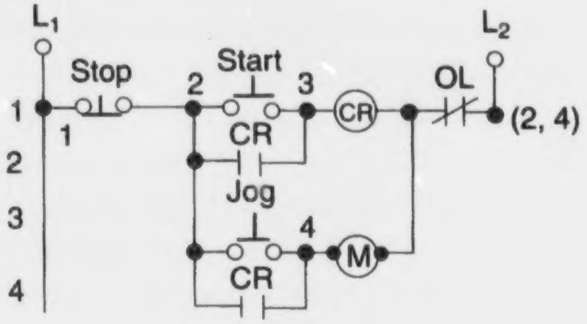


c. Two-circuit push button—The normally closed contacts of the two-circuit push button are in series with the memory contacts. The normally open contacts are used to energize the coil. When the jog button is pressed, the seal-in circuit is opened and the coil is energized. When the button is released, the coil is de-energized before the seal-in portion of the circuit closes again.

Caution: A control station using this circuit may maintain the circuit when the operator's finger is removed too quickly from the button. This could injure production workers, equipment, and machinery. Such a circuit is not recommended.



d. Control relay—The control relay is used to seal in the circuit. When the start button is depressed, the coil CR (control relay) is energized. When CR energizes, N/O contacts CR on rung 2 and 4 closes. CR rung 4 acts as seal-in for the starter's coil.


L_1
L_2
Stop
Start
2
3
OL
1
1
CR
(2, 4)
CR
2
Jog
3
4
M
CR
4

448

Unit 13 Reversing Starters

Unit Contents

Student Components

Student Page

Learning Activities Sheet 13–3

Objective Sheet 13–7

Information Sheet 13–9

* Assignment Sheets

1—Describe the Sequence of Operation of Ladder Diagrams 231
2—Determine the Number of Conductors Needed to Operate a Reversing Control 235

* Job Sheets

1—Wire a Reversing Starter with a Three-Position Selector Switch 237
2—Wire a Reversing Starter with One Control Station Using Auxiliary Contact and Mechanical Interlock 241
3—Wire a Reversing Starter with One Control Station Using Push Button Interlock and Auxiliary Contact Interlock 245
4—Wire a Reversing Starter with Two Control Stations 249
5—Wire Drum Switches 253
6—Wire a Reversing Starter with Jog in Both Directions 257

* Assignment Sheets and Job Sheets are located in Student Workbook 2.

Prerequisites:
None

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 3.

☐ 4. **Do** Assignment Sheet 1, "Describe the Sequence of Operation of Ladder Diagrams."

☐ 5. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 6. If the evaluation is not satisfactory, repeat Steps 3 and 4.

☐ 6. **Do** Assignment Sheet 2, "Determine the Number of Conductors Needed to Operate a Reversing Control."

☐ 7. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 8. If the evaluation is not satisfactory, repeat Steps 3 and 6.

☐ 8. **Do** Job Sheet 1, "Wire a Reversing Starter with a Three-Position Selector Switch."

☐ 9. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 10. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat Step 8.

☐ 10. **Do** Job Sheet 2, "Wire a Reversing Starter with One Control Station Using Auxiliary Contact and Mechanical Interlock."

☐ 11. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 12. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat Step 10.

☐ 12. **Do** Job Sheet 3, "Wire a Reversing Starter with One Control Station Using Push Button Interlock and Auxiliary Contact Interlock."

☐ 13. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 14. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat Step 12.

☐ 14. **Do** Job Sheet 4, "Wire a Reversing Starter with Two Control Stations."

☐ 15. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 16. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 4 and repeat Step 14.

☐ 16. **Study** Information Sheet, Objectives 4 and 5.

☐ 17. **Do** Job Sheet 5, "Wire Drum Switches."

☐ 18. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 19. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 5 and repeat Step 17.

☐ 19. **Do** Job Sheet 6, "Wire a Reversing Starter with Jog in Both Directions."

☐ 20. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 21. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 6 and repeat Step 19.

☐ 21. **Check** With instructor for any additional assignments to be completed.

☐ 22. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 23. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Objective Sheet

Unit Objective

After completing this unit, the student should be able to wire a reversing starter under various conditions. The student should demonstrate these competencies by completing the assignment sheets and job sheets, and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to reversing starters with their correct definitions.
2. Identify types of reversing starter construction.
3. List types of interlocking methods for reversing starters.
4. Identify types of drum controls.
5. Complete a drum switch diagram.
6. Describe the sequence of operation of ladder diagrams. (Assignment Sheet 1)
7. Determine the number of conductors needed to operate a reversing control. (Assignment Sheet 2)
8. Wire a reversing starter with a three-position selector switch. (Job Sheet 1)
9. Wire a reversing starter with one control station using auxiliary contact and mechanical interlock. (Job Sheet 2)
10. Wire a reversing starter with one control station using push button interlock and auxiliary contact interlock. (Job Sheet 3)
11. Wire a reversing starter with two control stations. (Job Sheet 4)
12. Wire drum switches. (Job Sheet 5)
13. Wire a reversing starter with jog in both directions. (Job Sheet 6)

Information Sheet

Objective 1

Terms and definitions

a. **Drum switch**—A switch having electrical connecting parts in the form of fingers held by spring pressure against contact segments or the surface of a rotating cylinder

b. **Mechanical interlocking**—Means of locking out contactors through the use of mechanical devices such as cams or blocks

c. **Push-button interlocking**—Means of interlocking reversing starters through the use of two-circuit push buttons with normally open and normally closed contacts

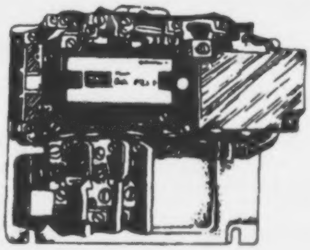
d. **Racing**—Condition that occurs when both forward and reversing push buttons are operated simultaneously; coils "race" to close

e. **Reversing starter**—Starter consisting of two identical contactors and one overload relay assembly; used in reversal of polyphase motors

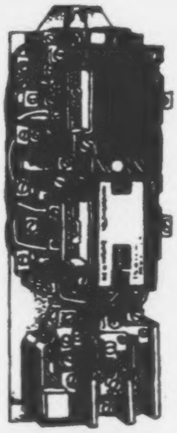
Objective 2

Types of reversing starter construction

a. Horizontal construction



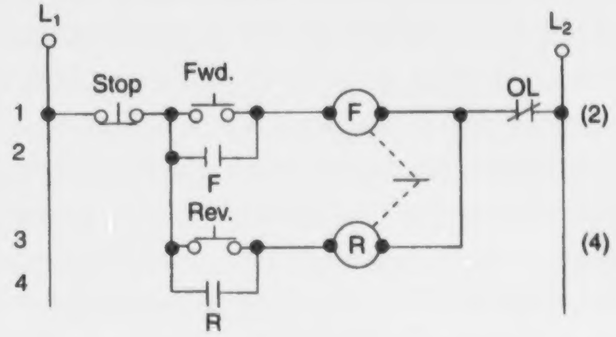
b. Vertical construction



Objective 3

Types of interlocking methods for reversing starters

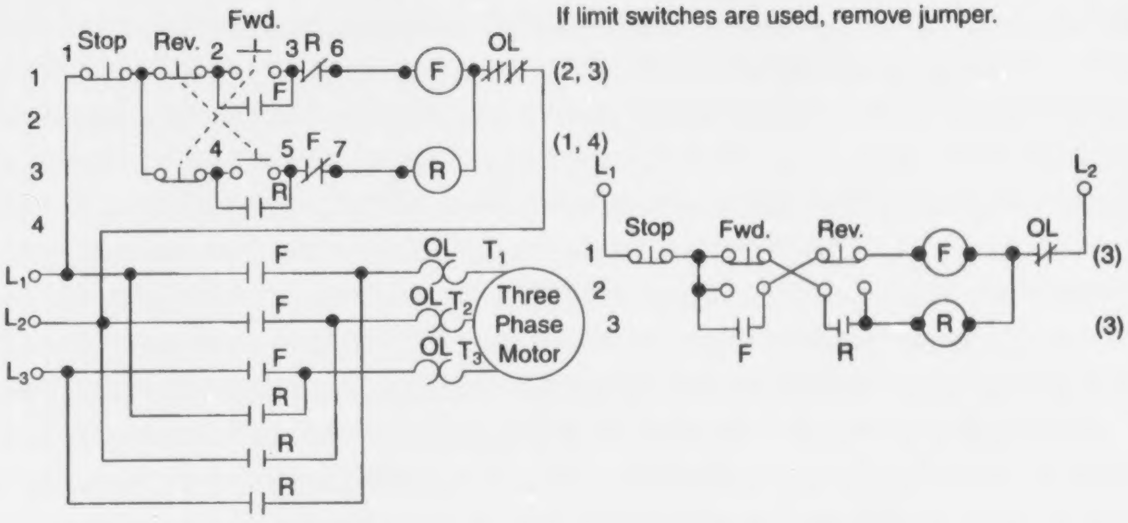
a. Mechanical interlocking


L₁
L₂
Stop
Fwd.
OL
1
2
3
4
F
F
R
R
Rev.
(2)
(4)

Note: A mechanical interlock is either factory or field installed between the forward and reverse contactors It locks out one contactor at the beginning of the stroke of either contactor. This prevents short circuits and burnouts.

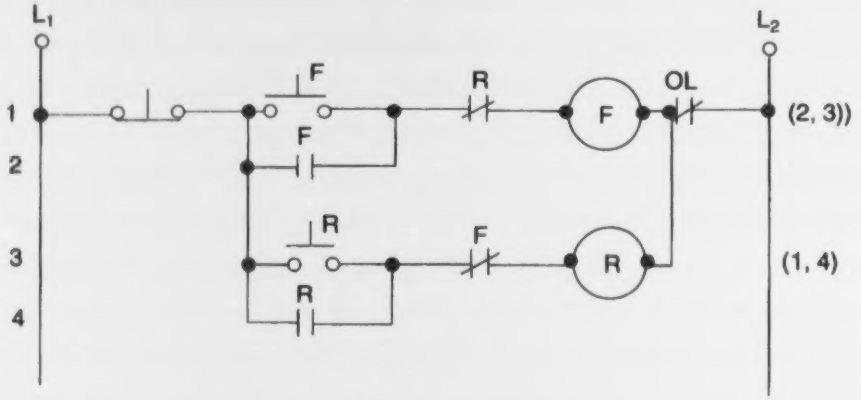
b. Push-button interlocking

If limit switches are used, remove jumper.


Fwd.
1 Stop
Rev.
2
3
R
6
OL
(2, 3)
1
2
3
4
F
F
R
4
5
F
7
R
(1, 4)
L₁
L₂
L₃
F
F
F
R
R
R
OL
T₁
OL T₂
OL T₃
Three Phase Motor
L₁
L₂
Stop
Fwd.
Rev.
OL
1
2
3
F
R
F
R
(3)
(3)

Note: This method will not allow the coils to race.

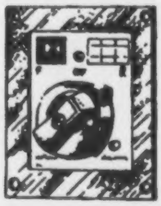
c. Auxiliary contact interlocking



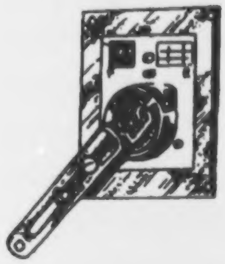
Objective 4

Types of drum controls

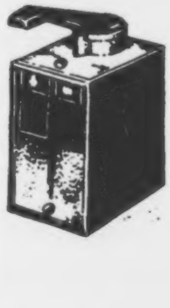
a. Flush mount knob operator



b. Flush mount adjustable operator



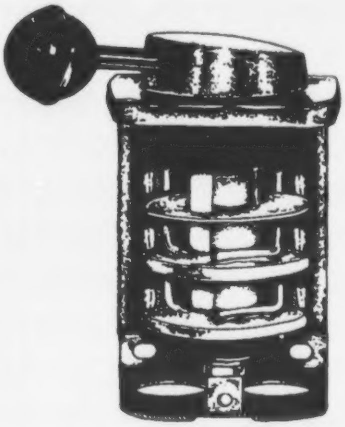
c. Surface mounting standard lever

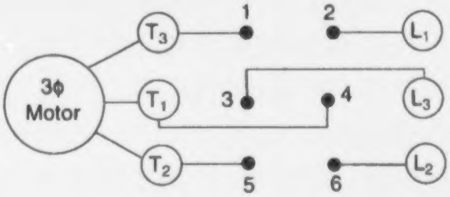


Objective 5

Drum switch diagrams

Note: Drum switches may be used as the only means of controlling a motor. However, if the starting inrush current is higher than the rating of the drum switch, a starter must be used.

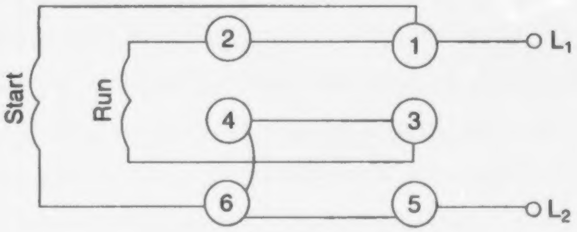



3φ
Motor
T_3
T_1
T_2
1
2
3
4
5
6
L_1
L_3
L_2

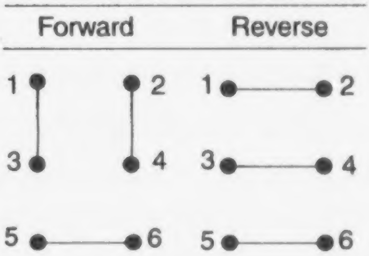
Connections for 3φ

Forward	Reverse
L_1 to T_3 L_2 to T_2 L_3 to T_1	L_1 to T_1 L_2 to T_2 L_3 to T_3

Single Phase


Start
Run
2
1
L_1
4
3
6
5
L_2

Connections for 1φ


Forward
Reverse
1
2
3
4
5
6
1
2
3
4
5
6

Special Control Circuits

Unit Contents

Student Components

Student Page

Learning Activities Sheet 14–3

Objective Sheet 14–5

Information Sheet 14–7

* Job Sheets

1—Build a Relay Control Circuit 259
2—Wire a Latching Relay or Contactor 263
3—Wire a Timed "On" Circuit 265
4—Wire a Timed "Off" Circuit 267
5—Energize Three Starters in a Timed Sequential Order 269
6—De-energize Three Starters in a Timed Sequential Order 273
7—Build a Ground Fault Indicator Circuit 277

* Job Sheets are located in Student Workbook 2.

Prerequisites:
None

Learning Activities Sheet

Student Name ____

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

📖 ☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 3.

☐ 4. **Do** Job Sheet 1, "Build a Relay Control Circuit."

☐ 5. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 6. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat Step 4.

☐ 6. **Study** Information Sheet, Objectives 4 and 5.

☐ 7. **Do** Job Sheet 2, "Wire a Latching Relay or Contactor."

☐ 8. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 9. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat Step 7.

☐ 9. **Study** Information Sheet, Objectives 6 and 7.

☐ 10. **Do** Job Sheet 3, "Wire a Timed "On" Circuit."

☐ 11. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 12. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat Step 10.

☐ 12. **Do** Job Sheet 4, "Wire a Timed "Off" Circuit."

☐	13.	**Stop**	Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 14. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 4 and repeat Step 12.
☐	14.	**Do**	Job Sheet 5, "Energize Three Starters in a Timed Sequential Order."
☐	15.	**Stop**	Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 16. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 5 and repeat Step 14.
☐	16.	**Do**	Job Sheet 6, "De-energize Three Starters in a Timed Sequential Order."
☐	17.	**Stop**	Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 18. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 6 and repeat Step 16.
☐	18.	**Study**	Information Sheet, Objectives 8 and 9.
☐	19.	**Do**	Job Sheet 7, "Build a Ground Fault Indicator Circuit."
☐	20.	**Stop**	Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 21. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 7 and repeat Step 19.
☐	21.	**Check**	With instructor for any additional assignments to be completed.
☐	22.	**Take**	Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.
☐	23.	**Stop**	Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Objective Sheet

Unit Objective

After completing this unit, the student should be able to design and build special control circuits. The student should demonstrate these competencies by completing the job sheets, and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to special control circuits with their correct definitions.
2. Identify the parts of a control relay.
3. List uses for control relays.
4. Identify the parts of a latching relay.
5. Describe the reason for using latching relays or contactors.
6. List types of timing relays.
7. Complete statements regarding applications for timing relays.
8. Describe how a ground fault indicator works.
9. Describe the use of an alarm silencing circuit.
10. Build a relay control circuit. (Job Sheet 1)
11. Wire a latching relay or contactor. (Job Sheet 2)
12. Wire a timed "on" circuit. (Job Sheet 3)
13. Wire a timed "off" circuit. (Job Sheet 4)
14. Energize three starters in a timed sequential order. (Job Sheet 5)
15. De-energize three starters in a timed sequential order. (Job Sheet 6)
16. Build a ground fault indicator circuit. (Job Sheet 7)

Information Sheet

Objective 1

Terms and definitions

a. **Accelerating contactors**—Contactors or relays used in starting motors at low speed, then increasing to maximum speed in preset timed steps

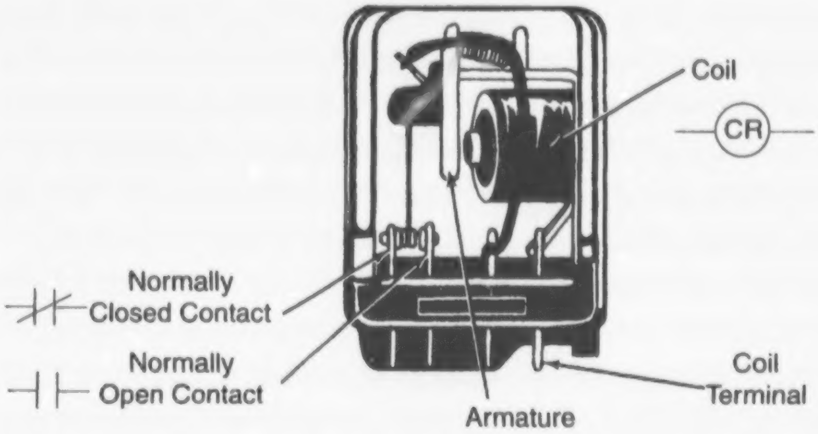
b. **Motor driven timing relay**—Relay whose timed contacts are operated through the action of a variable speed, extremely small motor

c. **Pneumatic timing relay**—Relay whose timed contacts are operated through the action of an air bellows and needle valve

d. **Solid state timing relay**—Relay whose timed contacts are operated by an electronic timer (microchip)

Objective 2

Parts of a control relay



Objective 3

Uses for control relays

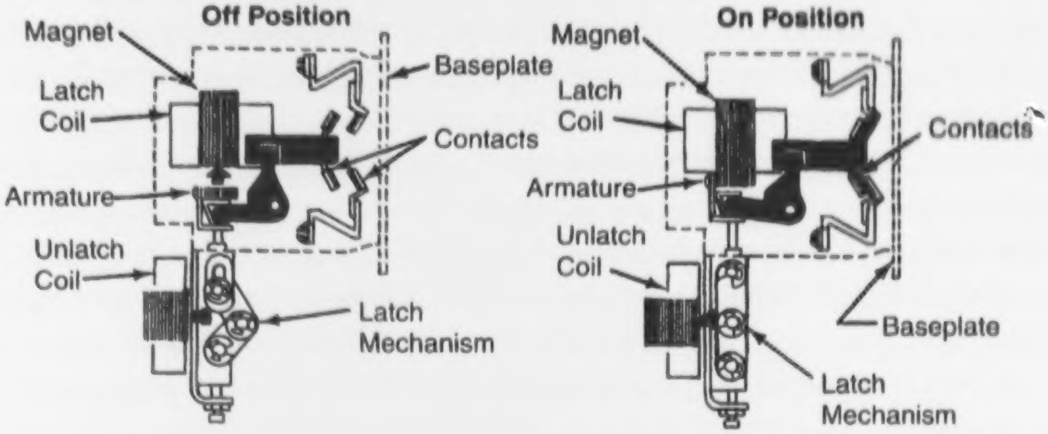
a. Control of fluid or pneumatic power valves

b. Control of multiple circuits

Information Sheet

Objective 4

Parts of a latching relay or contactor


Off Position
Magnet
Latch Coil
Armature
Unlatch Coil
Baseplate
Contacts
Latch Mechanism
On Position
Magnet
Latch Coil
Armature
Unlatch Coil
Contacts
Baseplate
Latch Mechanism

Objective 5

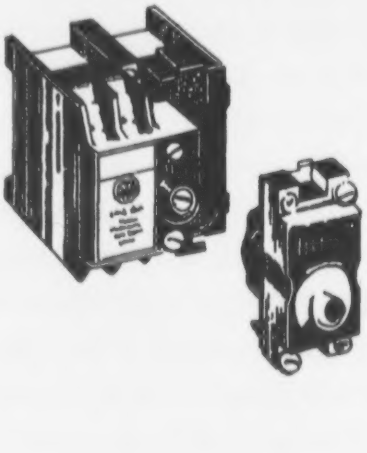
Reasons for using latching relays or contactors—To maintain contacts in their operated condition during power off periods

Note: Some applications include lighting contactors or control circuits that must remain on until a specific event occurs.

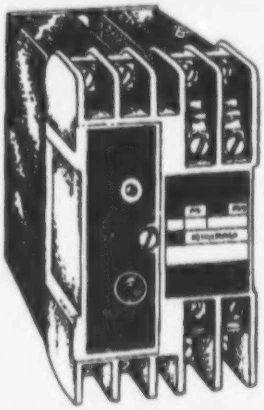
Objective 6

Types of timing relays

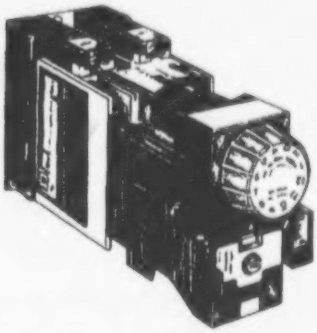
a. Pneumatic timing relay



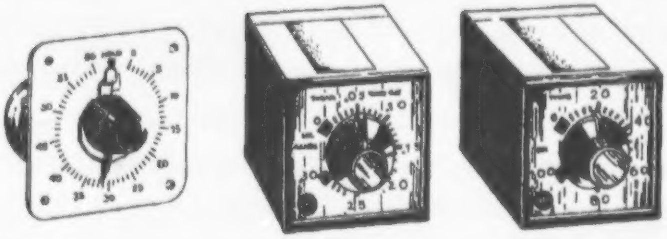
b. Solid state timing relay



c. Motor driven timing relay



d. Timers



Note: Timers require a manual operation of the timer to start operation. The device will run the selected time, then stop automatically.

Objective 7

Applications for timing relays

a. To control the accelerating contactors of motor starters

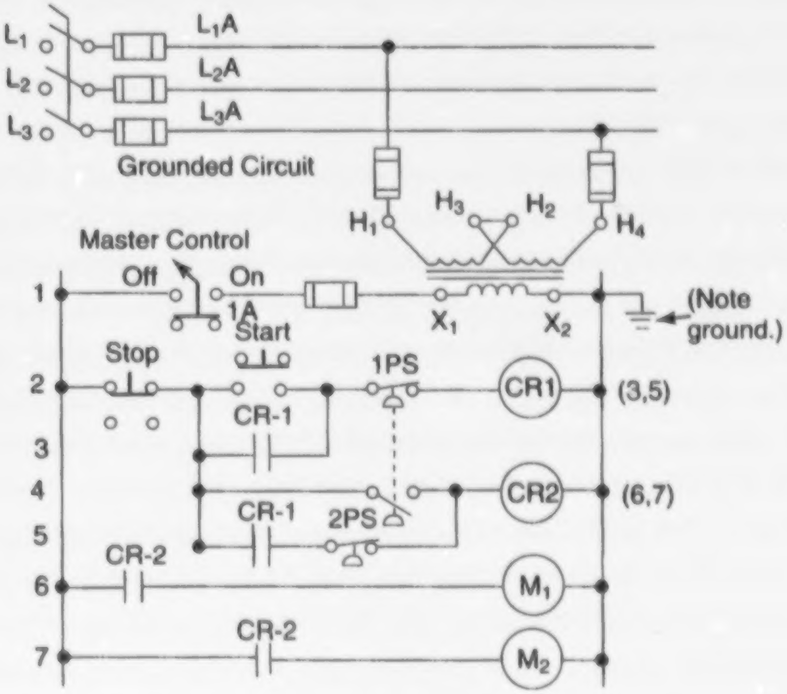
b. To control a timed sequential start-up of industrial machinery

c. To sequence on large loads for energy management systems

Objective 8

Ground fault indicator circuits

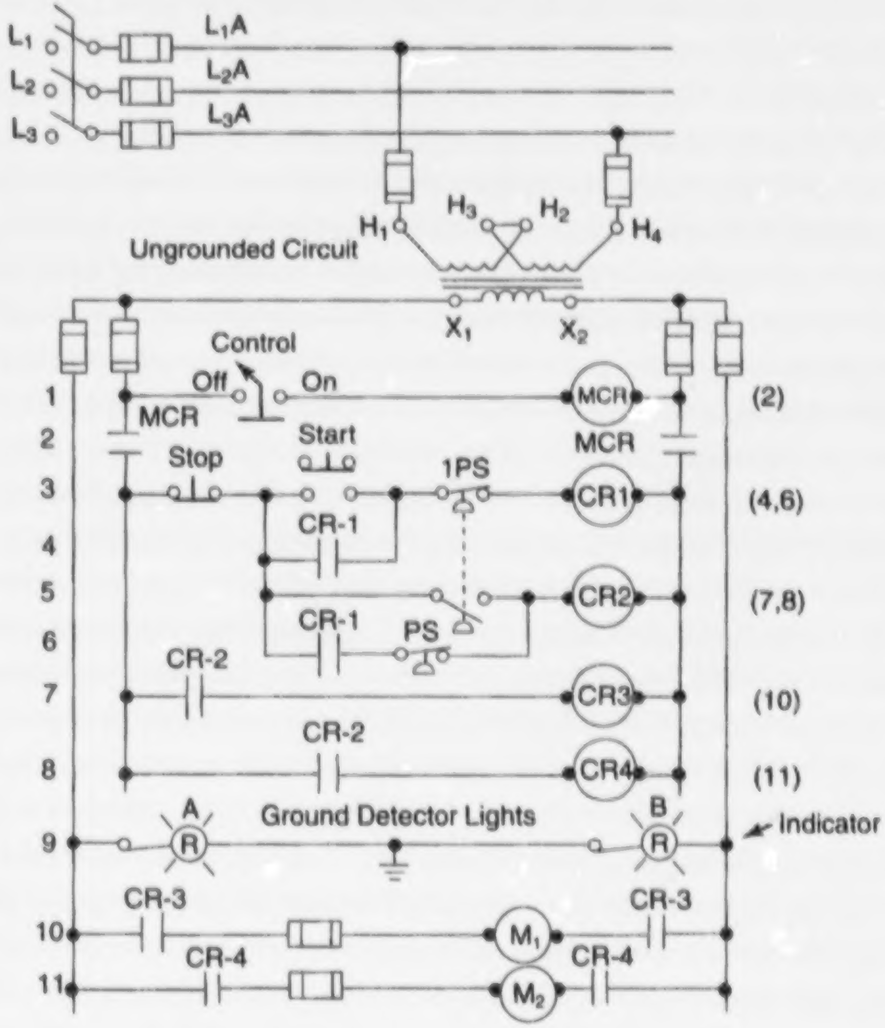
a. If a ground fault occurs in the control circuit, the fuse will blow, disabling the machine.



L1
L2
L3
L1A
L2A
L3A
Grounded Circuit
H1
H3
H2
H4
Master Control
Off
On
1A
X1
X2
(Note ground.)
1
2
3
4
5
6
7
Stop
Start
1PS
CR1
(3,5)
CR-1
CR2
(6,7)
CR-1
2PS
CR-2
M1
CR-2
M2

b. When the system has no grounds, both lights will glow at half brilliance because they are connected in series. If a ground occurs, the light on the side without the ground will glow at full brilliance. The ground will be on the side with the non-functioning light. In most cases a ground can occur and the system will continue to operate.

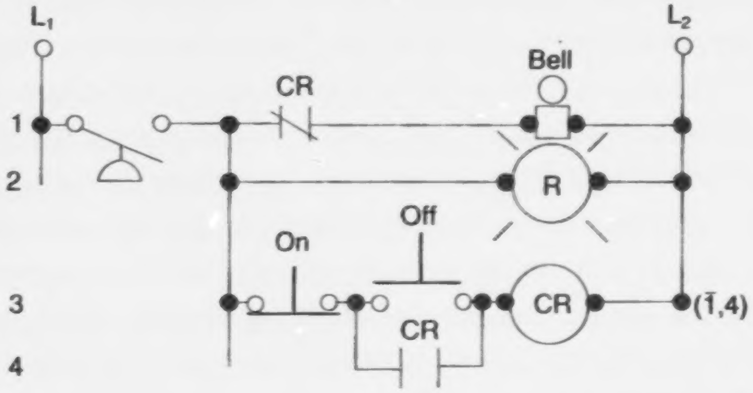
Note: This system is generally used on 208 or 480 volt wye systems with the lamps connected in a wye configuration.


L₁
L₂
L₃
L₁A
L₂A
L₃A
H₁
H₃
H₂
H₄
Ungrounded Circuit
X₁
X₂
Control
Off
On
MCR
MCR
MCR
1
2
Start
Stop
1PS
CR1
3
4
CR-1
5
CR2
6
CR-1
PS
7
CR-2
CR3
8
CR-2
CR4
(2)
(4,6)
(7,8)
(10)
(11)
A
B
R
R
Ground Detector Lights
Indicator
9
10
CR-3
CR-3
M₁
11
CR-4
CR-4
M₂

Information Sheet

Objective 9

Use of an alarm silencing circuit—Alarms are commonly used in industry to warn operators or other personnel of hazardous or dangerous conditions. Normally, the alarm will consist of an audible signal such as a horn or bell, and a visual signal such as a warning light. In this case, when an alarm condition occurs, the audible and visual alarms will activate and the maintenance personnel will silence the audible signal, but the visual signal will remain until the condition has been corrected.



Note: The push-button operators located on rung 3 are normally labeled "stop" and "start". In this case, however, they are labeled to describe their function in the circuit. If the bell and the light become energized in response to an increase in pressure, the "off" button can be used to silence the bell. The "on" button will allow the bell to ring if it is pressed. The light, however, can only be canceled in response to a decrease in pressure.

Unit 15 Programmable Logic Controllers

Unit Contents

Student Components

Student Page

Learning Activities Sheet 15–3

Objective Sheet 15–5

Information Sheet 15–7

* Assignment Sheets

1—Match I/O Devices With Their Functions 279
2—Convert Between Numbering Systems 281

* Assignment Sheets are located in Student Workbook 2.

Unit 15 Programmable Logic Controllers

Prerequisites:
None

Learning Activities Sheet

Student Name ________________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 12.

☐ 4. **Do** Assignment Sheet 1, "Match I/O Devices With Their Functions."

☐ 5. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 6. If the evaluation is not satisfactory, repeat Steps 3 and 4.

☐ 6. **Do** Assignment Sheet 2, "Convert Between Numbering Systems."

☐ 7. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 8. If the evaluation is not satisfactory, repeat Steps 3 and 6.

☐ 8. **Check** With instructor for any additional assignments to be completed.

☐ 9. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 10. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Objective Sheet

Unit Objective

After completing this unit, the student should be able to understand programmable logic controllers and distinguish between common input/output devices. The student should demonstrate these competencies by completing the assignment sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to programmable logic controllers with their correct definitions.
2. Select from a list programmable logic controller functions.
3. List the four parts of a programmable logic controller.
4. Identify input devices.
5. Identify output devices.
6. Identify components of a programmable logic controller.
7. Complete statements concerning states of contacts.
8. Name types of input/output modules.
9. Identify the parts of an optical coupler.
10. Identify the basic PLC ladder logic symbols.
11. Explain why a stop button is wired normally closed.
12. List the basic numbering systems used in programmable logic controllers.
13. Match I/O devices with their functions. (Assignment Sheet 1)
14. Convert between numbering systems. (Assignment Sheet 2)

Information Sheet

Objective 1

Terms and definitions

a. **Analog signal**—A signal that varies proportionally with some aspect of the environment

Example: The signal from a pressure transducer that varies with the amount of pressure being applied

b. **Counter**—A logic element in a PLC user program that is used to simulate the operation of electromechanical counters

c. **Discrete**—A two-state reference in the user program that can be either on or off

d. **Fiber optics**—Transfer of discrete signals through glass fibers with light

e. **Input**—A signal that provides the controller information about the system; can be discrete, numeric, or analog

f. **Logic**—A system that contains digital switching functions, circuits, or devices

g. **Networking**—Tying in of multiple PLCs to communicate with each other in the performance of a process

h. **Output**—A signal coming from the controller to field devices; can be discrete, numeric, or analog

i. **Programmer**—A device designed to allow inserting, monitoring, and editing a user program in the PLC

j. **Programmable logic controller (PLC)**—A solid state control system that contains a user programmable memory for the storage of instructions to perform specific functions in an operation

Objective 2

Programmable logic controller functions

a. The replacement of electromechanical relays, counters, timers, and analog devices with reliable solid-state circuitry

b. The facilitation of the change of a process at minimum expense and down time

c. The performance of arithmetic operations that might be required for controlling certain operations

d. Fault locating, alarming, and regulation of devices in a dangerous environment

e. The control of dangerous devices or devices in a dangerous environment.

Objective 3

Parts of a programmable logic controller

All programmable logic controllers have four basic major parts.

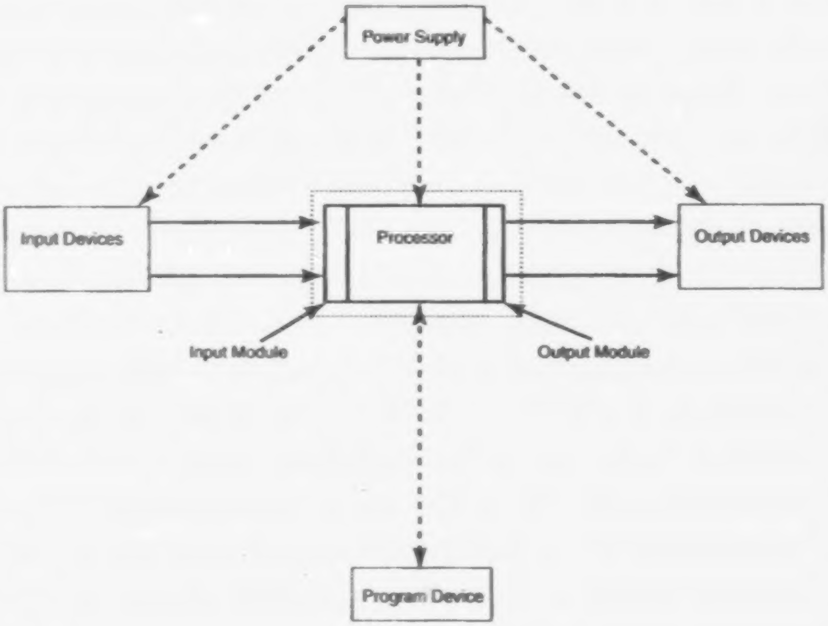
a. The power supply

b. The input modules to which the input devices (push buttons, limit switches, precision switches) are wired directly.

c. The processor which solves logic (AND, OR, NOT) that specifically control industrial devices such as motors, and allows control devices of varied voltages to be easily interfaced to provide simple or complex machine control.

d. The output modules to which output devices such as starters, counters, relays, timers, etc, are connected.

Note: The program device (software) is not considered the fifth part because some programs are erasable in some PLCs, and therefore are not considered part of the PLCs.


Power Supply
Input Devices
Processor
Output Devices
Input Module
Output Module
Program Device

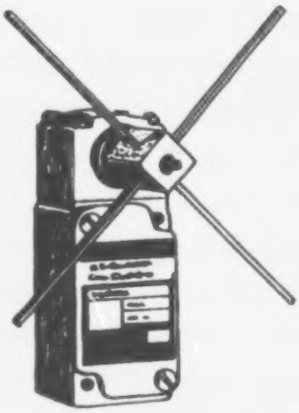
472

Objective 4

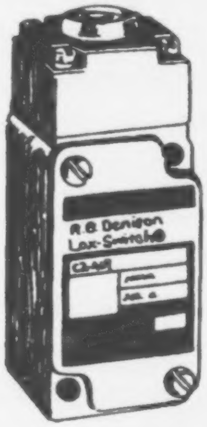
Input devices

a. Limit switches

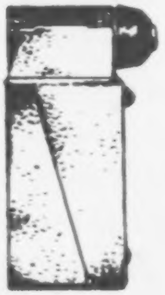
- Turnstile



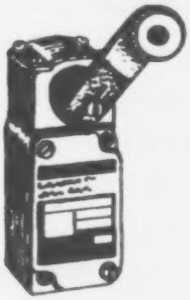
- Air operated


R.B. Denison
Lox-Switch®

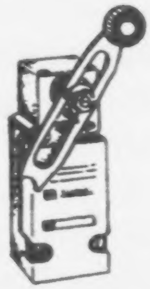
- Two-step sequence



- Turret head

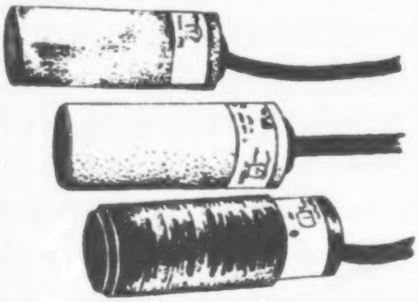


- Precision turret

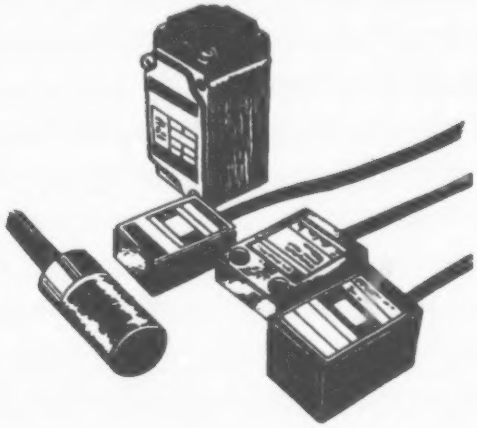


b. Proximity switches

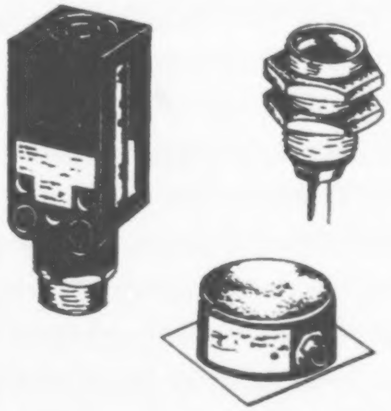
- Capacitive



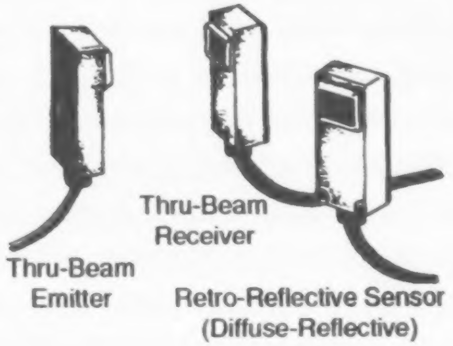
- Magnetic



- Inductive

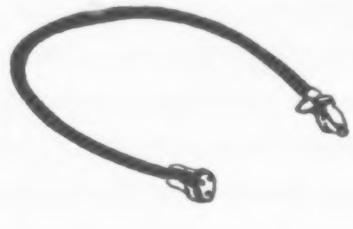


- Photoelectric

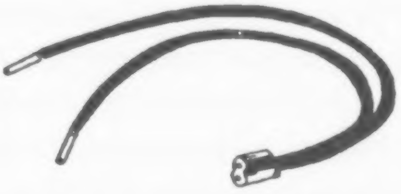

Thru-Beam Receiver
Thru-Beam Emitter
Retro-Reflective Sensor (Diffuse-Reflective)

c. Fiber optic probes

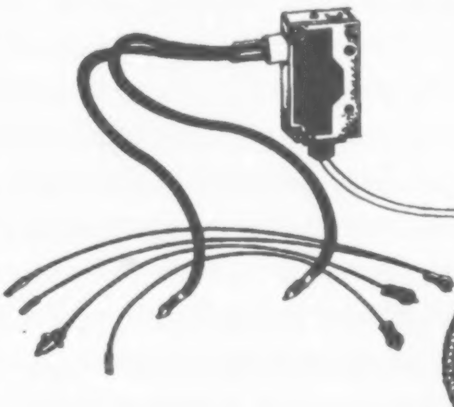
- Coaxial reflective



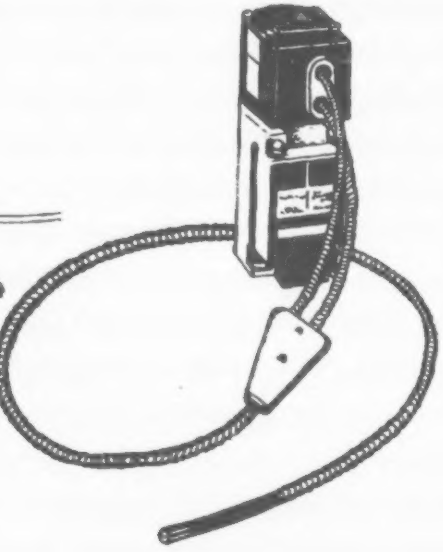
- Thru-beam



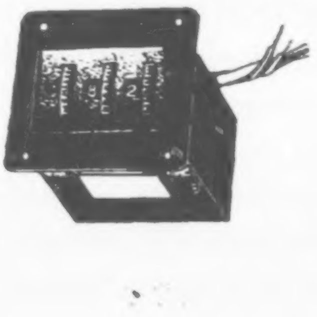
- Thru-beam and reflective scanners

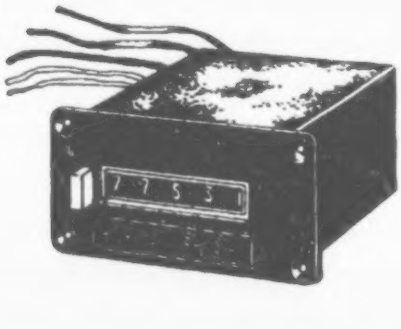


- Scanner cable

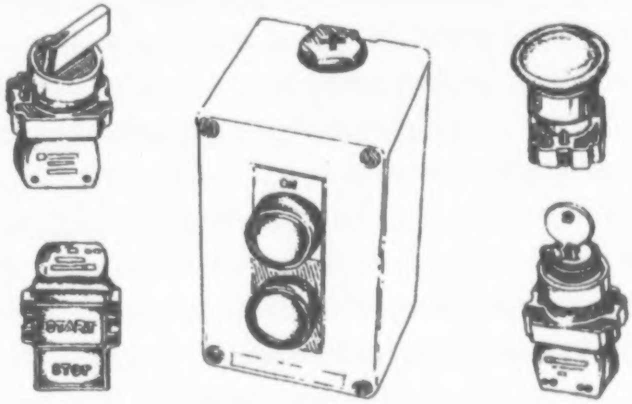


d. Thumbwheels





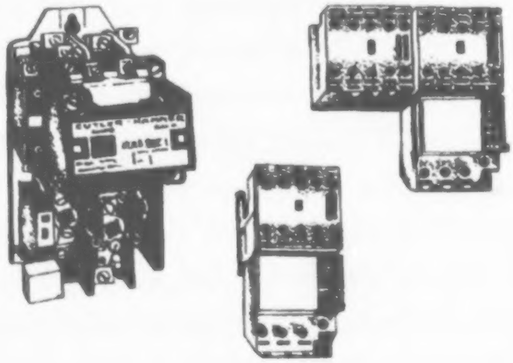
e. Push buttons



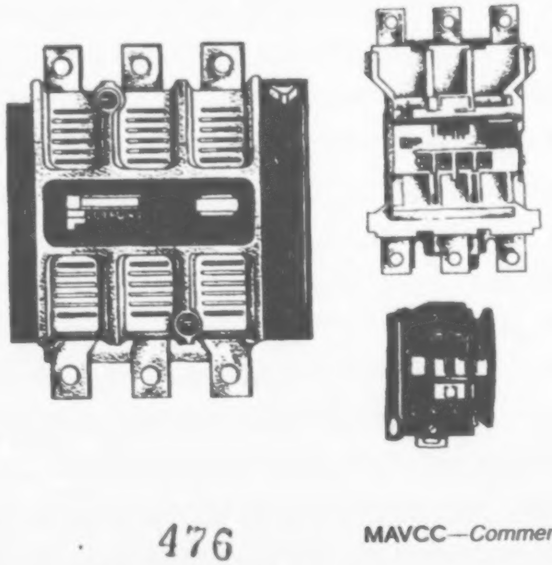
Objective 5

Output devices

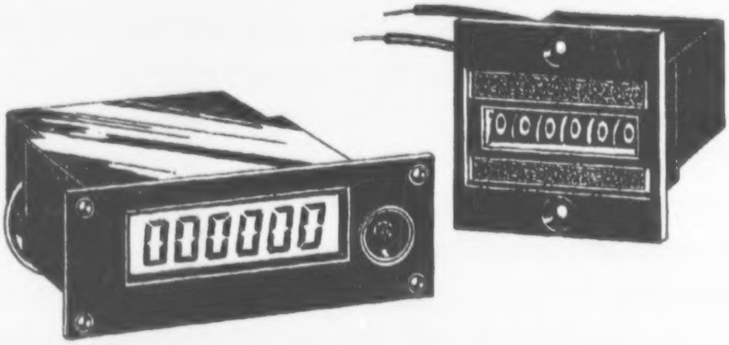
a. Motor starters



b. Contactors and relays

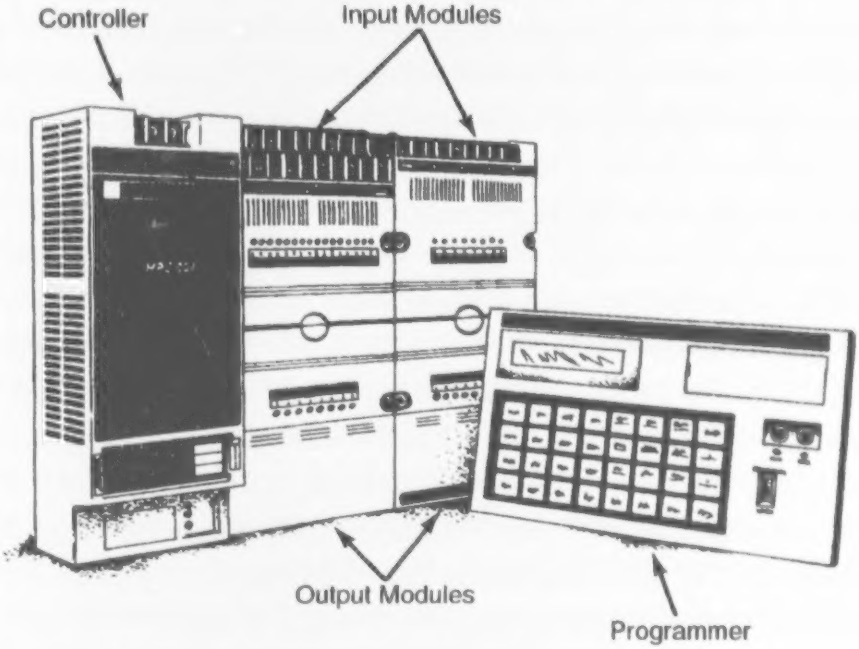


c. Counters



Objective 6

Components of a programmable logic controller


Controller
Input Modules
Output Modules
Programmer

Courtesy of Telemechanique

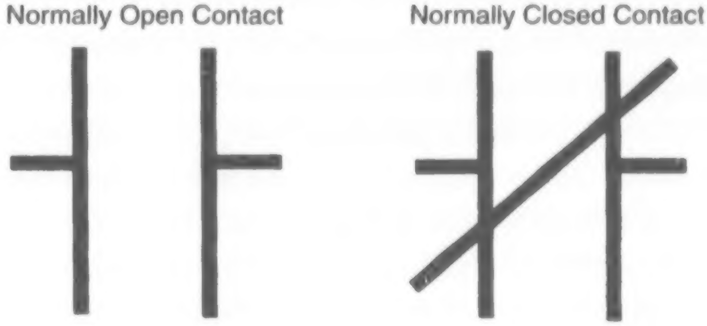
Objective 7

States of contacts

a. A normally closed contact will be closed and passing power when it is inactive.

b. A normally open contact will be open and not passing power when it is inactive.

c. When activated, contacts change to the opposite state from their normal (non-active) state. In other words, a normally open contact will close and a normally closed contact will open.



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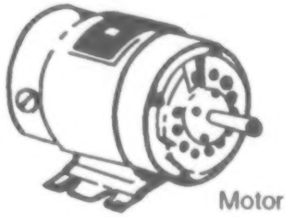
Note: It is important to remember that all relays have contacts associated with them that become active when the coil energizes. Switches also contain contacts that will go active when the switch is activated. All contacts have a normal state, either open or closed, that is the position they are in when they are inactive.

Objective 8

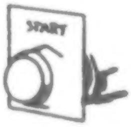
Types of Input/Output (I/O) modules

a. Discrete I/O modules

Note: These are used for simple two-state, on/off field devices.



Motor

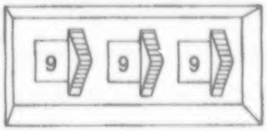


Push Button

b. Numerical I/O modules

Note: These are used for field devices such as thumbwheels and LED readouts, which send and receive numbers.

Thumbwheel

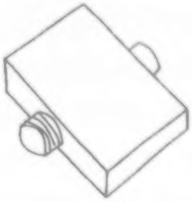


LED Display

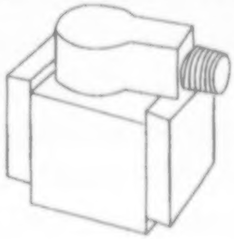
c. Analog I/O modules

Note: These are used for field devices which must send or receive voltage signals that change continuously.

Pressure Transducer

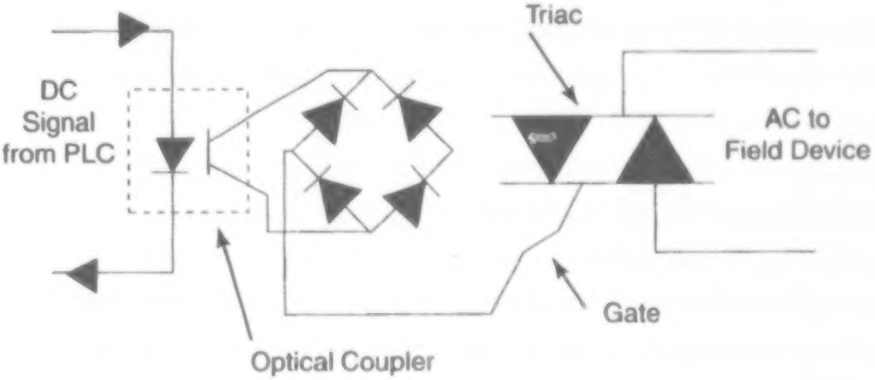


Proportional Analog Valve



Objective 9

Parts of an optical coupler



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Note: Two basically independent circuits meet at a triac, which is an electronic switch. When the low voltage DC signal from the PLC is applied to the gate of the triac, a switch in the triac will close, allowing AC to flow in the output device's circuit. This system is used to optically isolate the PLC circuitry from the field circuitry, thus protecting the PLC from transients, spikes, etc.

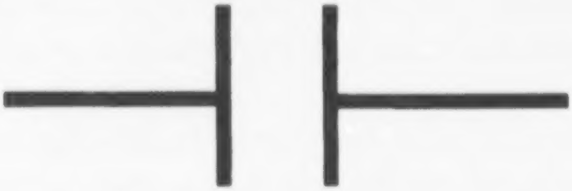
Information Sheet

Objective 10

Basic ladder logic symbols

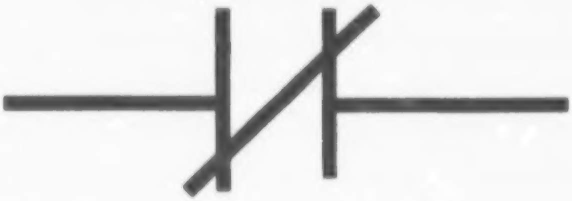
Note: Signals from the input devices in the field are changed by the I/0 modules into data which the PLC can use. When this data is a simple on/off signal, it enters the logic through contacts on ladder rungs in the user program.

a. Normally open contact (examine on)



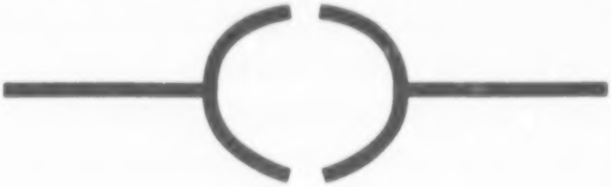
Note: Normally open contacts are contacts that remain open and do not pass power when they are not receiving a signal from the input module. They are sometimes called examine on contacts because they are looking for an on signal to pass power.

b. Normally closed contacts (examine off)



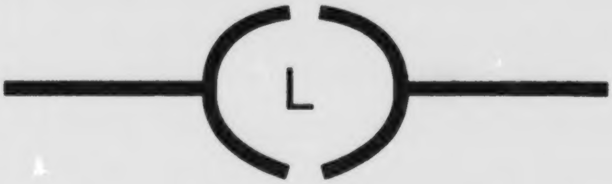
Note: Normally closed contacts are contacts that remain closed and do pass power when they are not receiving a signal from the input module. They are sometimes called examine off contacts because they are looking for an off signal to pass power.

c. Normal output coils



Note: Normal coils have two states. They can be energized and sending a signal to the output module or not energized and not sending a signal.

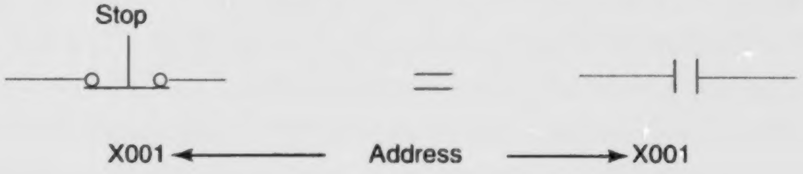
d. Latched output coils



Note: These are often referred to as retentive coils. On most controllers, a latched coil will remain in its latched state, even when the rung changes state. When this is the case, an unlatching coil is often required to change the state of the output. Consult the PLC's User Manual for the details on latching coils in your controller.

Objective 11

Normally closed stop buttons—Input devices such as stop switches and high limit switches are wired normally closed in the field. However, in the logic, the normally closed contact is programmed normally open. The N/C input device is passing power to the I/0 module. Sensing this voltage, the I/0 sends an on signal to the controller. Since this signal means the device has not been activated, power will flow along the rung as long as the signal is received.



Objective 12

Basic number systems

Note: Most programmable logic controllers can perform at least some arithmetic. They do this by comparing the values in one register to one or more different registers.

a. Decimal (Base 10)

b. Binary (Base 2)

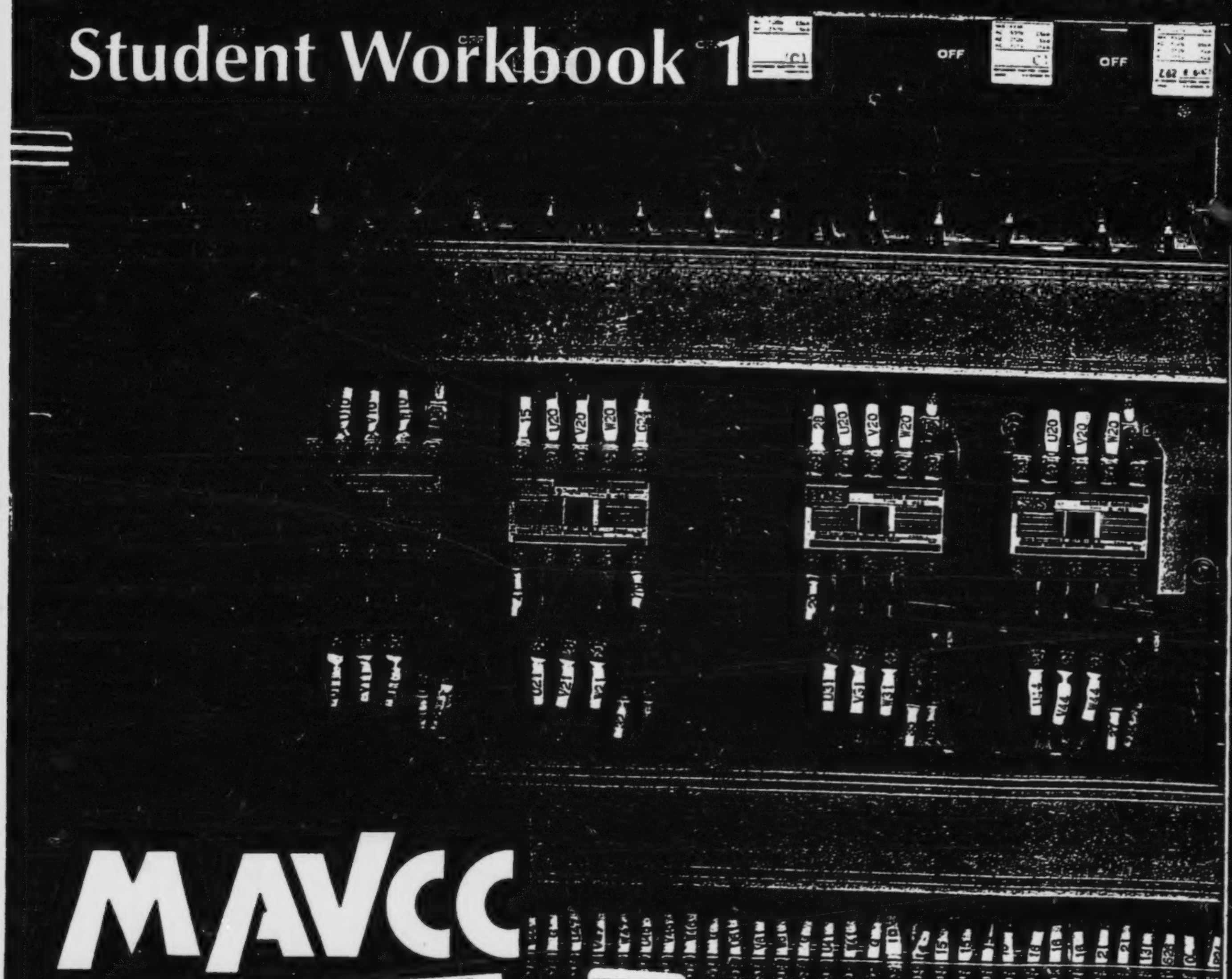
c. Octal (Base 8)

d. Hexidecimal (Base 16)

COMMERCIAL AND INDUSTRIAL WIRING

Fourth Edition

Student Workbook 1



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Commercial and Industrial Wiring

Fourth Edition

Student Workbook 1

Units 1–8

Written by

Stan Kaltwasser
Gary Flowers

Revised by

Dan Ipock

Project coordinated by

Glenn Fleming

Developed by

Multistate Academic and Vocational Curriculum Consortium, Inc.
1500 West Seventh Avenue
Stillwater, Oklahoma 74074-4364

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For more information, contact the
Multistate Academic and Vocational Curriculum Consortium
1500 West Seventh Avenue
Stillwater, OK 74074-4364

E-mail: mavcc@mavcc.com
Internet: http://www.mavcc.org
Phone: (800)654-3988 or (405)743-5578

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Objective 15

Focus Assignment—Select Participants and Describe Their Functions at a Construction Site

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Selected valid participants from the list	______
• Listed the correct function of each selected participant	______

Basic Skills

Reading

Critical Thinking

Introduction

Game rules and regulations are a means for participants to reach a common understanding of the game. These participants include the opposing teams who compete for points, the referee or umpires, who manage and direct the game, the owners, who manage the financial and logistic aspects of the game, and the spectators who pay to watch and cheer the teams as they play. Like game rules and regulations, construction blueprints provide a means for participants on a construction job to communicate ideas and directions about the job.

Directions

Working in a group of 2 to 5 students, name the main participants and the function of each at a construction site. Choose participants from the following list:

Food Manger
Architect
Part-time Worker
Principal
Teacher
Instructor
Driver
Professor
Programmer
Construction Worker
Auto Mechanic
Banker
Owner
Politician
Engineer

Objective 16

Assignment Sheet 1—Construct an Electrical Blueprint

Name ______________________ Overall Rating ____________

Date ______________________

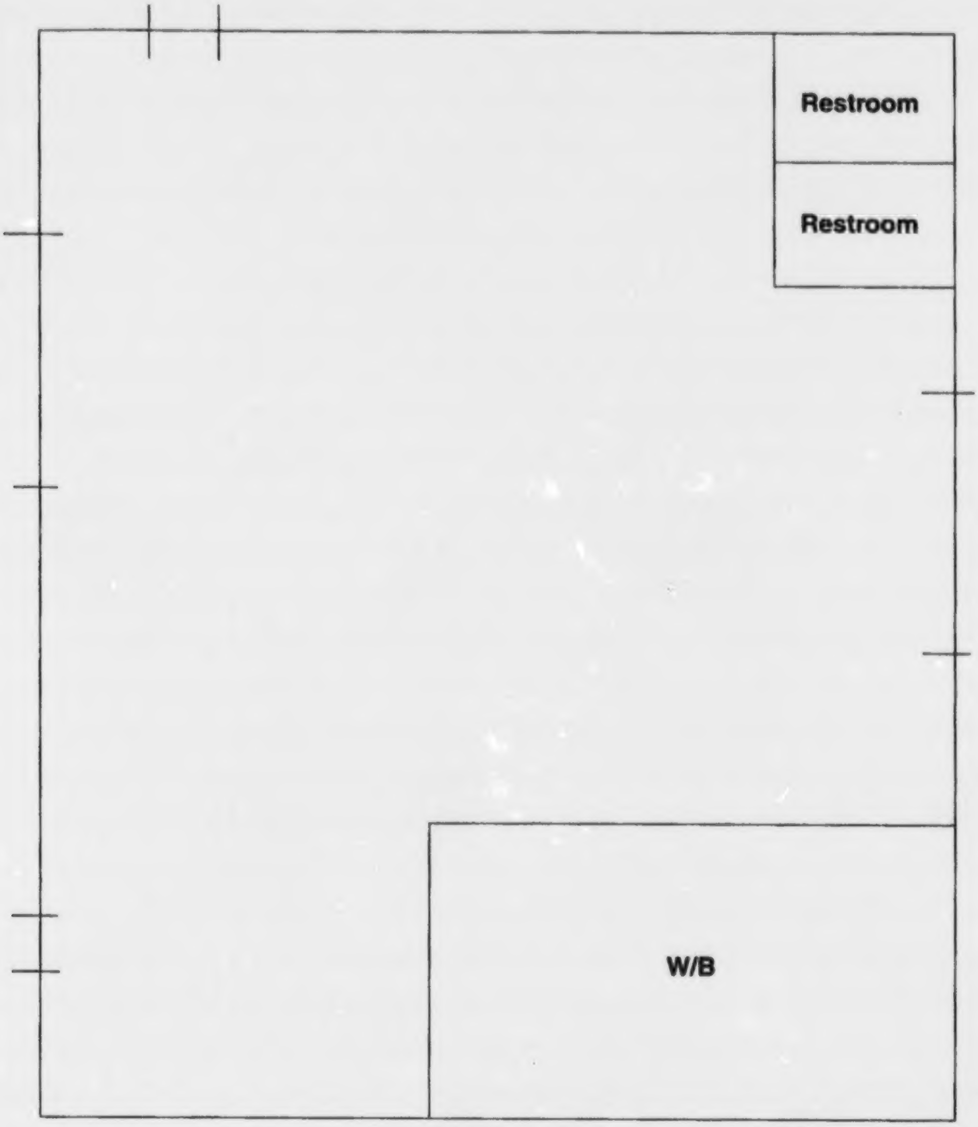
Evaluation Criteria	Rating
• Ability to apply basic concepts	_____
• Correct symbols used	_____
• Diagram drawn to scale and represents correct plan specifications	_____

Basic Skills

Reading Writing Critical Thinking

Directions

Using the electrical symbols found in the Information Sheet and the outline on the next page, construct an electrical drawing of a garage with two restrooms, office, shop area, and wash bay. Include a vertical pump, air compressor, and blowers in your construction. The above criteria will be used to evaluate your performance.


Restroom
Restroom
W/B

Objective 17

Assignment Sheet 2—Perform Load Calculations and Determine Overcurrent Protection and Conductor Size

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Used sizing information correctly	______
• Gave accurate answers	______

Basic Skills

Reading

Mathematics

Directions

Using the following information and the *National Electrical Code*, size the fuses shown on the line diagram. The information given is for dual element time delay fuses. The above criteria will be used to evaluate your performance.

Refer to Article 220.10 for sizing feeders.
Refer to Article 430 for information on sizing motor fuses.
Refer to Article 450 for information on sizing transformer overcurrent protection
Refer to Article 460 for information on sizing overcurrent protection for capacitors.
Refer to Article 230.95 for information pertaining to ground fault protection of service equipment.

1. **Main service**—Size the fuse according to th method described in 4.

2. **Feeder with no motor load**—The fuse size must be at least 125% of the continuous load plus 100% of the non-continuous load.

3. **Feeder with all motor loads**—The fuse must be sized at 150% of the full load current of the largest motor plus the full load current of all other motors.

4. **Feeder circuit with mixed loads**—Size the fuse at the sum of:

   a. 150% of the full load current of the largest motor,
   b. 100% of the full load current of all other motors,
   c. 125% of the continuous, nonmotor load, and
   d. 1000% of the non-continuous, nonmotor load.

5. **Branch circuit with no motor load**—The fuse must be sized at least 125% of the continuous load plus 100% of the non-continuous load. (Do not size larger than the ampacity of the conductor.)

6. **Motor branch circuit with overload relays**—When overload relays are sized to provide running overload protection, a and b below will provide ground fault and short circuit protection.

   a. **Motors with 1.15 service factor or 40 degrees C rise**—Size fuse at 125% of motor full load current or next higher standard size.

   b. **Motors with less than 1.15 service factor or over 40 degrees C rise**—Size the fuse at 115% of the motor full load current or the next higher standard fuse size.

7. **Motor branch circuit with fuse protection only**—Where the fuse is the only motor protection, the following fuses will provide motor running overload and short circuit protection.

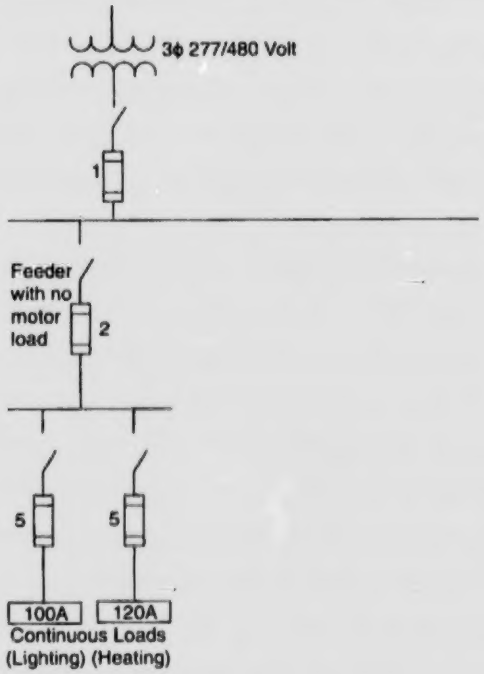
   a. **Motors with 1.15 service factor or 40 degrees C rise**—Size fuse at 110% to 125% of motor full load current.

   b. **Motors with less than 1.15 service factor or over 40 degrees C rise**—Size the fuse at 100% to 115% of the motor full load current.

8. **Large motor branch circuit**—For large motors (larger than 600 amperes), fuse at 150% to 225% of the full load current of the motor, depending on the starting method; i.e. part-winding starting or reduced voltage starting.

9. **Transformer primary fuse (with secondary fuse protection)**—Overcurrent protection may be sized at 250% of the transformer primary current.

10. **Transformer secondary fuse**—Size the fuse at no more than 125% of the secondary full load current.


3ϕ 277/480 Volt
1
Feeder with no motor load
2
5
5
100A
120A
Continuous Loads
(Lighting) (Heating)

a. The 100A continuous load will require what size fuse and what size THHN conductor?

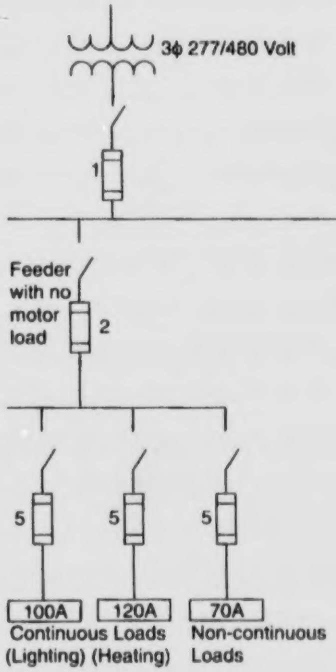
Fuse ____________________

Conductor ________________

b. The 120A continuous load will use what size fuse and what size THHN conductor?

Fuse ____________________

Conductor ________________


3ϕ 277/480 Volt
1
Feeder with no motor load
2
5
5
5
100A
120A
70A
Continuous Loads
(Lighting) (Heating)
Non-continuous Loads

c. The non-continuous 70A load will need what size THWN conductor, and what size fuse?

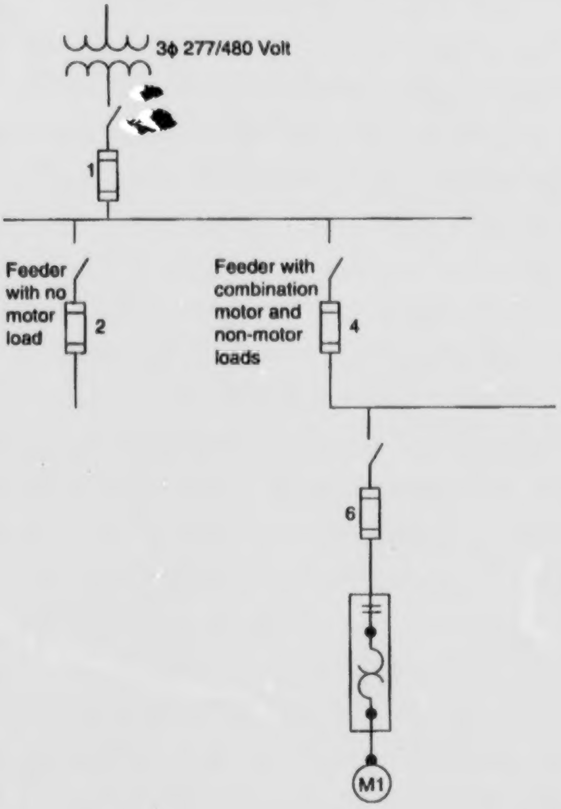
Fuse ____________________

Conductor _______________

d. The feeder with no motor loads will require what size fuse, and what size THW conductor?

Fuse ____________________

Conductor _______________

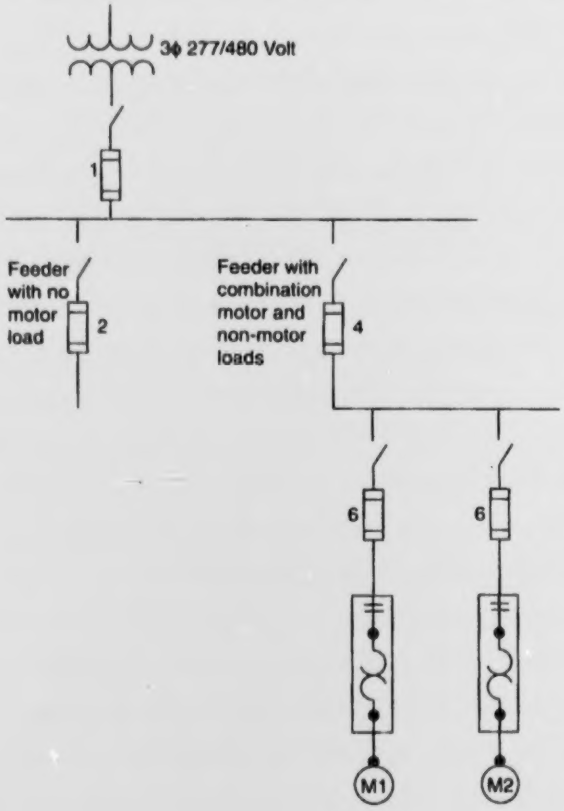

3ϕ 277/480 Volt
1
Feeder with no motor load
2
Feeder with combination motor and non-motor loads
4
6
M1

e. Motor M1* requires what size of fuse and what size of TW conductor?

Fuse ____________________

Conductor ________________

*Motor Loads: M1 - 15 HP 3ϕ 1.15 SF
Follow steps described on the Information Sheet, Objective 11 a-e.

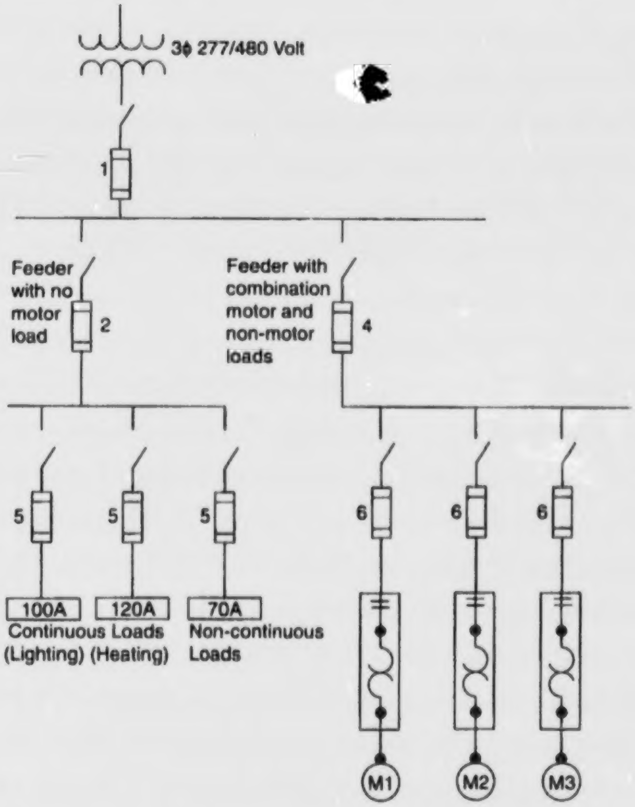

3ϕ 277/480 Volt
1
Feeder with no motor load
2
Feeder with combination motor and non-motor loads
4
6
6
M1
M2

f. Motor M2* will need a fuse of what amperage and what size TW conductor?

Fuse ____________________

Conductor ________________

*Motor Loads: M2 - 15 HP 3ϕ 1.15 SF
Follow steps described on the Information Sheet, Objective 11 a-e.

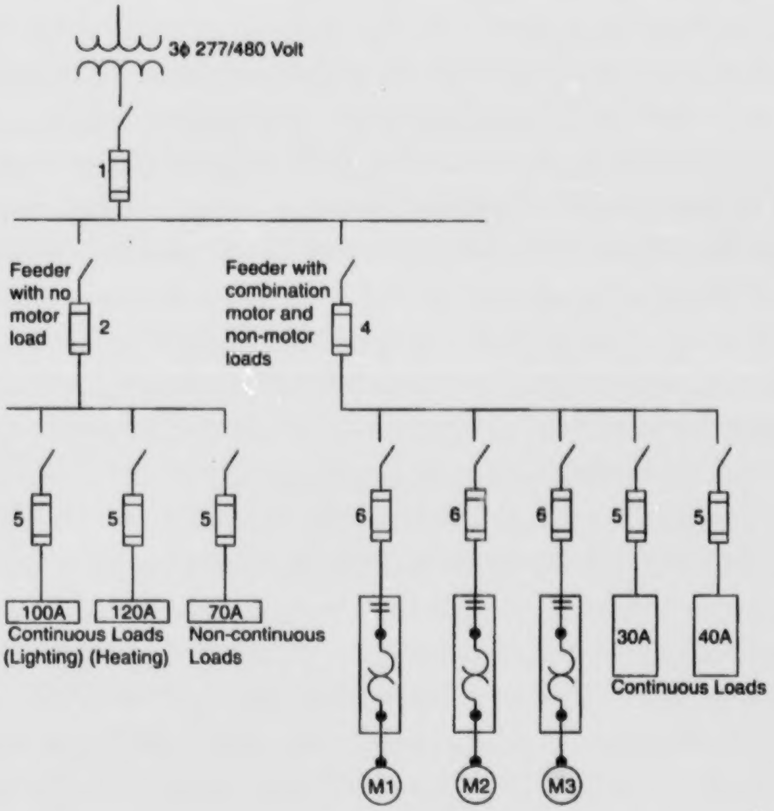

3ϕ 277/480 Volt
1
Feeder with no motor load
2
Feeder with combination motor and non-motor loads
4
5
5
5
6
6
6
100A
120A
70A
Continuous Loads
(Lighting) (Heating)
Non-continuous Loads
M1
M2
M3

g. The motor marked M3* will require what size THHN branch circuit conductor and what size fuse?

Fuse ____________________

Conductor ________________

*Motor Loads: M3 - 25 HP 3ϕ 1.00 SF
Follow steps described on the Information Sheet, Objective 11 a-e.


3ϕ 277/480 Volt
1
Feeder with no motor load
2
Feeder with combination motor and non-motor loads
4
5
5
5
6
6
6
5
5
100A
120A
70A
Continuous Loads
(Lighting) (Heating)
Non-continuous Loads
30A
40A
Continuous Loads
M1
M2
M3

h. The 30A continuous load will need what size of fuse and what size THHN conductor?

Fuse ____________________

Conductor ________________

i. The 40A continuous load will need what size fuse and THHN branch circuit conductor?

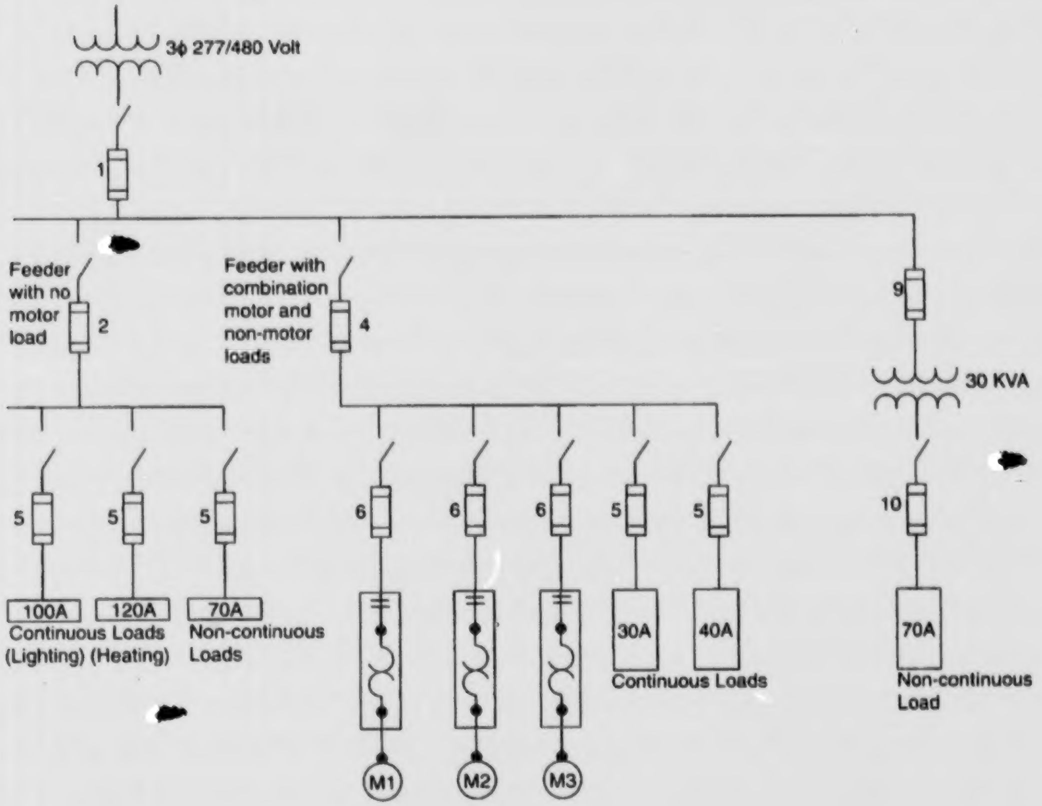
Fuse ____________________

Conductor ________________

j. The feeder with a combination of motor and non-motor loads will need what size fuse and THHN conductor?

Fuse ____________________

Conductor ________________


3ϕ 277/480 Volt
1
Feeder with no motor load
2
Feeder with combination motor and non-motor loads
4
9
30 KVA
10
5
5
5
6
6
6
5
5
100A
120A
70A
Continuous Loads
(Lighting) (Heating)
Non-continuous Loads
30A
40A
Continuous Loads
70A
Non-continuous Load
M1
M2
M3

k. The 70A non-continuous load will require what size fuse and what size THW conductor?

Fuse ____________________

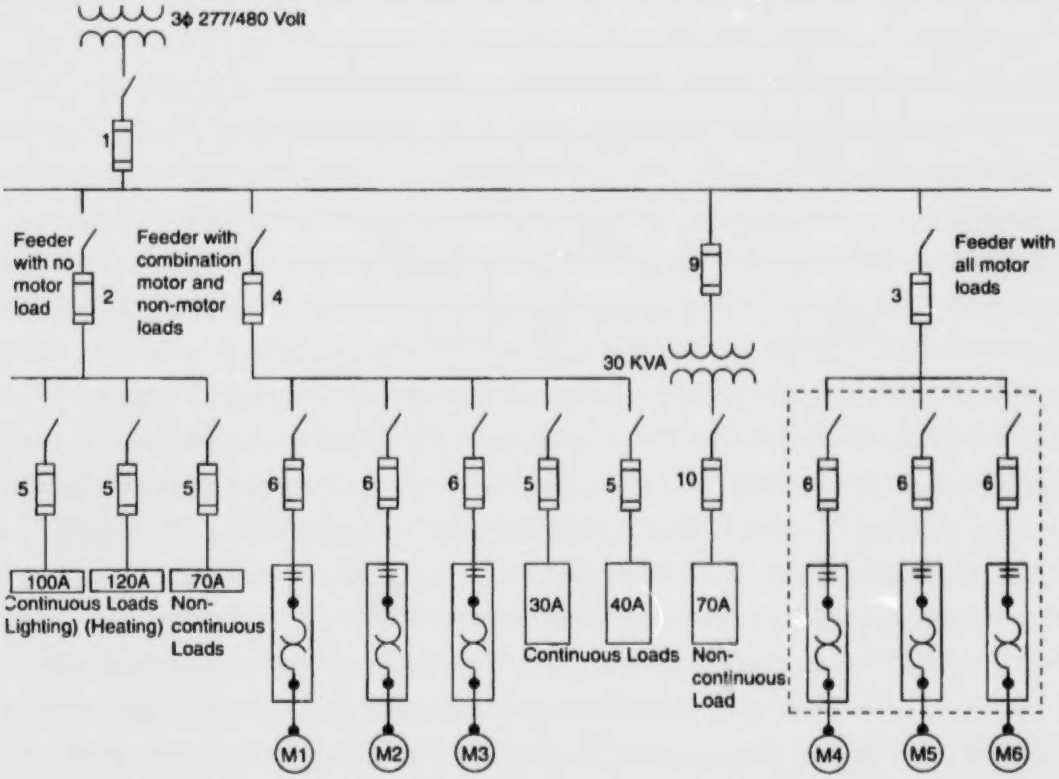
Conductor ________________

l. The fuse and THW conductor suppling the 30KVA transformer will need to be what size?

Fuse ____________________

Conductor ________________

Assignment Sheet 2


3ϕ 277/480 Volt
1
Feeder with no motor load
2
Feeder with combination motor and non-motor loads
4
9
30 KVA
3
Feeder with all motor loads
5
5
5
6
6
6
5
5
10
6
6
6
100A
120A
70A
Continuous Loads
(Lighting) (Heating)
Non-continuous Loads
30A
40A
Continuous Loads
70A
Non-continuous Load
M1
M2
M3
M4
M5
M6

m. Motor M4* will require what size fuse and what size of THHN conductor?

Fuse ______________________

Conductor __________________

n. Motor M5* will need what size fuse and what size THWN conductor?

Fuse ______________________

Conductor __________________

o. Motor M6* will need what size fuse and THWN branch circuit conductor?

Fuse ______________________

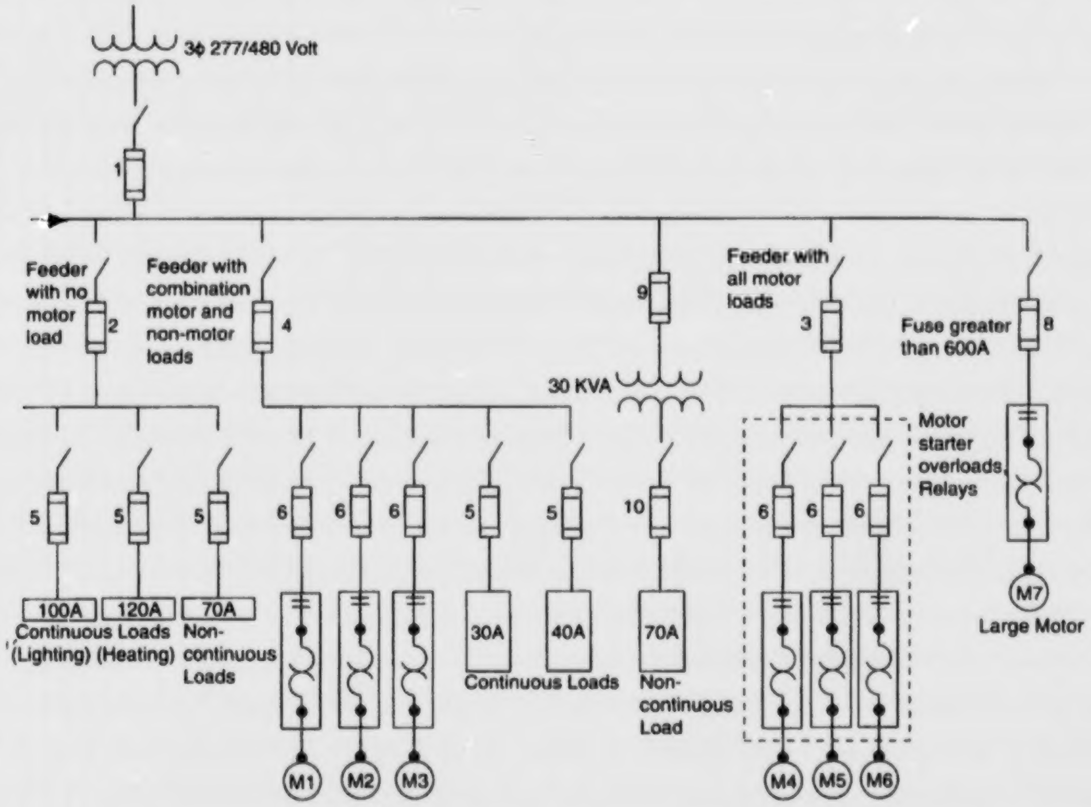
Conductor __________________

p. The feeder with all motor loads will require what size fuse and THHN conductor?

Fuse ______________________

Conductor __________________

* •Motor Loads: M4—15 HP 3ϕ 40° C rise
M5—5 HP 3ϕ 1.00 SF
M6—5 HP 3ϕ 1.00 SF


3ϕ 277/480 Volt
1
Feeder with no motor load
2
Feeder with combination motor and non-motor loads
4
9
30 KVA
Feeder with all motor loads
3
Fuse greater than 600A
8
Motor starter overloads, Relays
5
5
5
6
6
6
5
5
10
6
6
6
100A
120A
70A
Continuous Loads
(Lighting) (Heating)
Non-continuous Loads
30A
40A
Continuous Loads
70A
Non-continuous Load
M1
M2
M3
M4
M5
M6
M7
Large Motor

q. The conductor and fuse for the large motor* will need to be what size?

Fuse ____________________

Conductor ________________

r. The main service fuse and THWN conductor will need to be what size?

Fuse ____________________

Conductor ________________

*Motor Load: M7—425 HP 3ϕ 1.00 SF
FLC = 660A; Part winding starter

Objective 18

Assignment Sheet 3—Compute Lighting Loads

Name ______________________________ Overall Rating __________

Date ______________________________

Evaluation Criteria	**Rating**
• Referred to correct sections of *NEC*	______
• Computed lighting loads correctly	______

Basic Skills

Reading Mathematics

Directions

Using *NEC* article 220.3 and Table 220.3(A), compute the following lighting loads. The above criteria will be used to evaluate your performance.

a. Bank building with 4500 sq. ft. 120V/230, 1 ϕ.

____

b. Restaurant with dining area 736 sq. ft. 277V/480, 3ϕ.

____

c. School with a classroom of 860 sq. ft. 120V/240, 3ϕ.

____

d. Auditorium in a school having 7430 sq. ft. 277V/480, 3ϕ.

____

e. Barber shop having 450 sq. ft. of floor for cutting hair at 120V/230, 1ϕ.

____

Objective 19

Assignment Sheet 4—Determine Maximum Numbers of Conductors in Conduit

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	**Rating**
• Ability to apply basic concepts	_____
• Correct answers	_____

Basic Skills

Reading Mathematics

Directions

Determine the maximum number of conductors in conduit and tubing for the problems below. The above criteria will be used to evaluate your performance.

a. Tubing fill for #12 THW wires in $^1/_2$"(16) electrical metallic tubing.

____

b. Tubing fill for #8 RHW wires in 1$^1/_4$"(35) electrical non-metallic tubing.

____

c. Conduit fill for #14 TW wires in 2$^1/_2$"(63) flexible metal conduit.

____

d. Conduit fill for #3/0 THW wires in 3"(78) intermediate metal conduit.

____

e. Conduit fill for #10 THWN wires in 1"(27) liquidtight flexible metal conduit.

____

f. Conduit fill for #14 TW wires in 3"(78) rigid metal conduit.

____

g. Conduit fill for #14 THWN wires in 3"(78) rigid PVC conduit.

____

Objective 20

Assignment Sheet 5—Determine Wire Sizes to Prevent Excessive Voltage Drop

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	**Rating**
• Proper use of NEC	______
• Accurate calculations	______
• Correct answers	______

Basic Skills

Reading Critical Thinking Mathematics

Directions

Voltage drop is directly proportional to resistance and current. Therefore the longer a conductor and the greater the current, the greater the voltage drop will be. While the *NEC* mandates no requirements concerning voltage drop, it does provide three recommendations to size conductors to prevent an excessive amount of voltage drop. See Article 210.19 (A) (FPN No. 3), Article 215.2 (D) (FPN No. 2), and Article 310.15 (FPN). Basically, these three recommendations limit voltage drop on branch circuits to 3%, voltage drop on feeders is also limited to 3%, and a 5% maximum voltage drop is recommended overall. Using a constant (K) of 12 and the following formulas, determine the proper wire size needed to prevent the voltage drop from exceeding 3%. Show your work. The above criteria will be used to evaluate your performance.

For single phase use: $VD = \frac{2L \times K \times I}{A}$

For three phase use: $VD = \frac{L \times K \times I \times 1.732}{A}$

K = A constant of 12, L = Length in feet, I = Current in amperes

a. What size copper conductors are required for a 240 volt, 2-wire branch circuit, with an 80 amp load? The one way length is 115 feet.

Wire size = ____________________

b. Determine the copper wire size for a branch circuit pulling 22 amps located 150 feet from the source. The voltage is 230.

Wire size = ____________________

c. A feeder has a load of 125 amps at 240 volts, and it is 100 feet from the source. What size wire is needed?

Wire size = ____________________

d. A 460 volt 3 phase feeder will serve a load of 300 amps. The distance from the point of attachment with the power company is 230 feet. What size conductor will be required?

Wire size = ____________________

Objective 9

Focus Assignment—Describe a Tool, and Suggest Changes to Increase Its Efficiency

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Answered all questions	______
• Used proper grammar, format, and spelling	______

Basic Skills

Reading Writing Critical Thinking

Introduction

Early man used the first tool (stone) to produce a fire. Since the Stone age, tools have evolved and take on different shapes and forms because of changing technology. New tools must be developed and older tools are changed to meet new requirements.

Directions

Working alone or in a group of 2 to 5 people, answer the following questions.

- Describe a common hand or power tool you have used. Be creative in your choice.
- Did the tool help you accomplish the work you were performing?
- How difficult would the work have been without the tool? Explain.
- What improvements would you make to the tool to make it function more efficiently?

Be prepared to discuss your conclusions in class.

Focus Assignment Sheet

Objective 10

Job Sheet 1—Bend, Cut, Ream, and Thread One-Half-Inch Rigid Metal Conduit

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	_____
• Proper cut	_____
• 90° bend on pipe	_____
• Correct thread depth and length	_____
• Workmanship	_____
• Compliance to *NEC*	

Basic Skills

Reading

Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Eye protection
- Hacksaw
- 10-foot piece of 1/2-inch (16) rigid metal conduit
- Reaming tool
- 3/4-inch (21) EMT bender with handle
- Reaming tool
- 1/2-inch (16) conduit pipe die
- Cutting oil
- Hickey pipe vise
- Measuring tape
- Marking pencil

Procedure

☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Put on eye protection.

☐ 4. Measure and mark conduit for 18-inch stub-up.

Note: Check 3/4-inch (21) EMT bender for take up.

☐ 5. Place bender on conduit with "B" on bend mark.

☐ 6. Bend conduit,holding **heavy** foot pressure on bender.

☐ 7. Use hacksaw to cut off stub-up and 90-degree bend.

☐ 8. Place cut off piece of conduit in vise for threading.

☐ 9. Ream inside ends of conduit.

☐ 10. Thread end of stub, using 1/2-inch (16) conduit pipe die and plenty of cutting oil.

☐ 11. Remove die and examine threads.

Note: If the die was good and an adequate amount of cutting oil was used, the threads will be smooth with sharp ridges.

☐ 12. If threads are ragged, cut them off and repeat steps 10 and 11.

☐ 13. Return tools and materials to proper storage.

☐ 14. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 11

Job Sheet 2—Bend EMT Stub-Ups

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Stub measured 11″ from floor	______
• EMT cut square	______
• Reamed properly	______
• Workmanship	______

Basic Skills

Reading

Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Measuring tape
- Marking pencil
- 1/2-inch (16) EMT bender with handle
- 10-foot piece of 1/2-inch (16) EMT
- Hacksaw
- Eye protection

Procedure

☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Measure and mark tubing 11 inches from end to be bent.

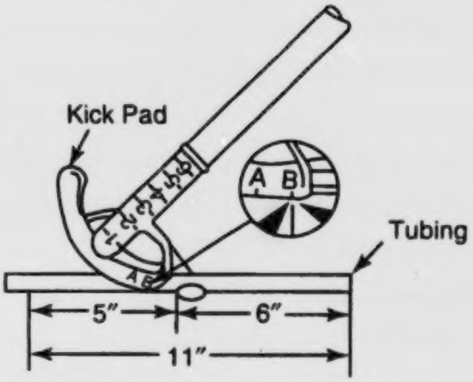
☐ 4. Subtract 5 inches from mark made in step 1; mark this measurement.

Note: This measurement varies for each size tubing.

☐ 5. Put on eye protection

☐ 6. Place conduit bender on tubing in position to bend toward unmarked end of tubing.

Figure 1



☐ 7. Place bender mark "B" on mark made in step 4.

☐ 8. Position tubing and bender on the floor with one foot on the bender heel, keeping bender mark "B" on the conduit mark.

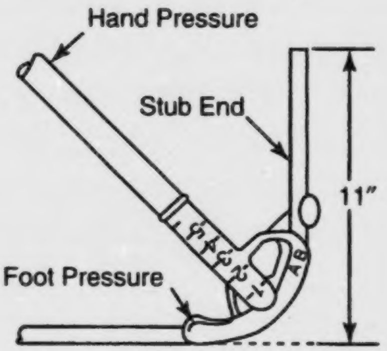
☐ 9. Place heavy foot pressure on the bender kick pad.

☐ 10. Make one sweeping movement of the bender handle until the tubing is perpendicular to the floor.

☐ 11. Before removing the bender, measure the height of tubing end above the floor.

Note: If the bend is an exact 90 degrees, the end will be 11 inches above the floor.

Figure 2



☐ 12. Remove the bender.

☐ 13. Use a hacksaw to cut off the bent end of tubing.

☐ 14. Practice the procedure by repeating steps 3 through 13 as many times as possible, using up the 10 feet of tubing.

☐ 15. Return tools and materials to proper storage.

☐ 16. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 12

Job Sheet 3—Make Back-to-Back Bends on One-Half-Inch EMT

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Bent to proper dimensions	______
• Straight cut	______
• EMT reamed properly	______
• Workmanship	______
• Compliance to *NEC*	______

Basic Skills

Reading Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- 10 feet of 1/2-inch (16) EMT
- Republic bender or similar
- Hacksaw
- Measuring tape
- Marking pencil
- Eye protection

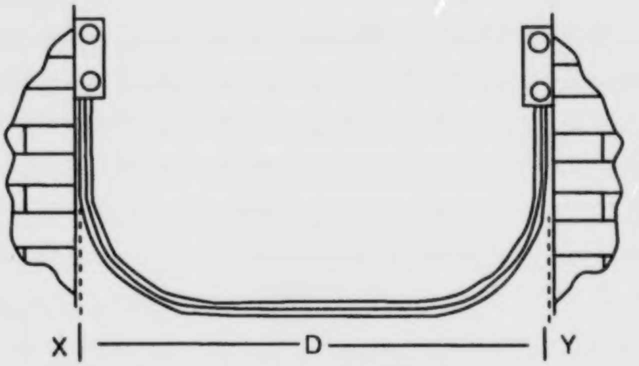
Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Measure 30 inches from distance D shown in Figure 1.

Figure 1



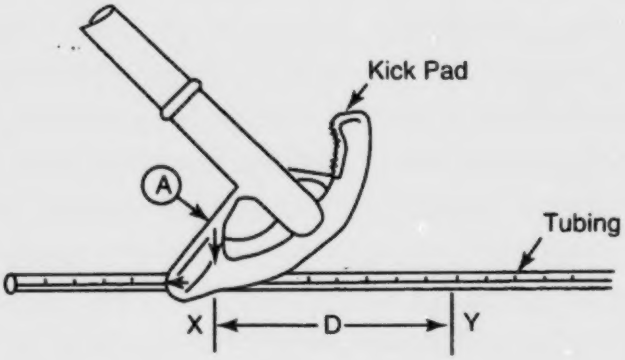
Used with permission of Republic Steel Corporation.

☐ 4. Mark tubing at points X and Y (D distance) shown in Figure 1.

☐ 5. Put on eye protection.

☐ 6. Place bender point "A" on tubing at point X as shown in Figure 2.

Figure 2



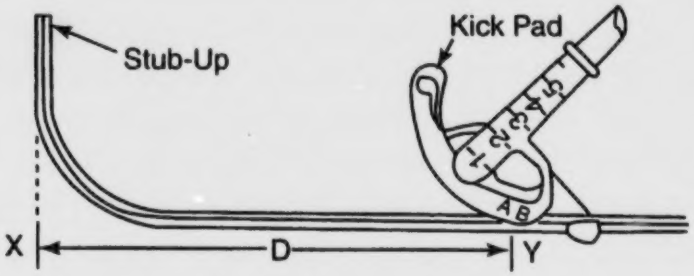
☐ 7. Place heavy foot pressure on bender kick pad.

☐ 8. Make on sweeping movement with bender handle until tubing is perpendicular to floor.

☐ 9. Remove bender.

☐ 10. Place bender mark "A" on tubing at point Y in position to bend *toward* point X; make sure that stub-up (made in step 5) points straight up.

Figure 3



Used with permission of Republic Steel Corporation.

☐ 11. Repeat steps 7 and 8.

☐ 12. Remove bender.

☐ 13. Check distance from back to back.

Note: If bender point "A" did not slip and bends are truly 90 degrees, the measurement will be 30 inches, the distance of D.

☐ 14. Use hacksaw to cut off bent end of tubing.

☐ 15. Practice procedure by repeating steps 3 through 14 as many times as possible, using up the 10 feet of tubing.

☐ 16. Return tools and materials to proper storage.

☐ 17. Clean the work area.

Evaluator's Comments: ____________________

____

____

Objective 13

Job Sheet 4—Make Offset Bends on One-Half-Inch EMT

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Accurate bends	______
• Cut EMT straight	______
• Reamed EMT	______
• Workmanship	______
• Compliance to *NEC*	

Basic Skills

Reading Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- $^1/_2$-inch (16) EMT bender
- 10 feet of $^1/_2$-inch (16) EMT
- Measuring tape
- Marking pencil
- Hacksaw
- Eye protection

Procedure

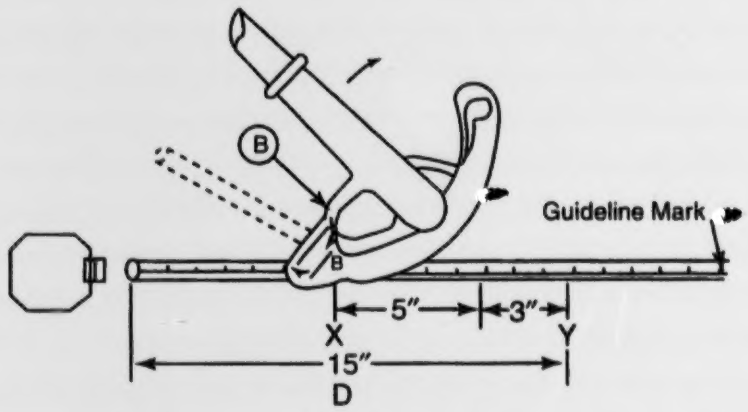
☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Measure 15 inches from end of tubing for distance D shown in Figure 1.

Note: This measurement represents the distance from the outlet box to the object to be passed.

Figure 1



☐ 4. Mark tubing at point Y shown in Figure 1.

☐ 5. Measure back 8 inches from point Y, and mark tubing at this measurement to establish point X.

Note: The 8-inch number is determined by taking half the height of the offset and adding 5 inches.

☐ 6. Put on eye protection.

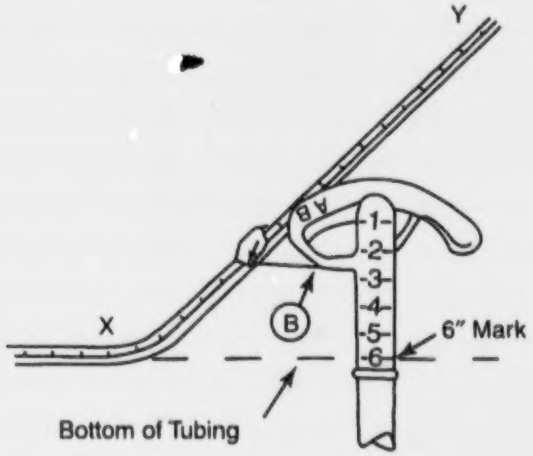
☐ 7. Place bender point "B" on tubing at point X, with bender in position to bend toward object to be passed.

☐ 8. Make 45-degree bend.

☐ 9. Remove bender.

☐ 10. Reverse the tubing and slip the end of it through holding hook on bender so that the lower part of the 45-degree bend is in line with the 6-inch depth measurement on side of bender as shown in Figure 2; mark tubing at point B.

Figure 2



Used with permission of Republic Steel Corporation.

☐ 11. Remove bender, and place on tubing with bender point "B" at 6-inch mark.

☐ 12. Make 45-degree bend.

☐ 13. Remove bender.

Note: This step completes the offset.

☐ 14. Use hacksaw to cut off offset.

☐ 15. Practice procedure at least five times, making 1-inch, 2-inch, 3-inch, 4-inch, and 5-inch offsets.

☐ 16. Return tools and materials to proper storage.

☐ 17. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 14

Job Sheet 5—Bend and Install One-Half-Inch EMT

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	____
• Pipe measurement correct	____
• EMT measurements correct	____
• 90° bends accurate	____
• Tubing fastened securely	____
• Workmanship	____
• Compliance to *NEC*	____

Basic Skills

Reading Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools
- Eye protection
- Hacksaw
- $^{1}/_{2}$-inch (16) conduit bender
- 20 feet of $^{1}/_{2}$-inch (16) EMT
- Two 4-inch square outlet boxes with mounting screws
- Space to install 20 feet of tubing with three 90-degree bends and a 4-inch square box at each end
- Four $^{1}/_{2}$-inch (16) one-hole straps, or other supports
- EMT couplings and connectors, setscrew or raintight

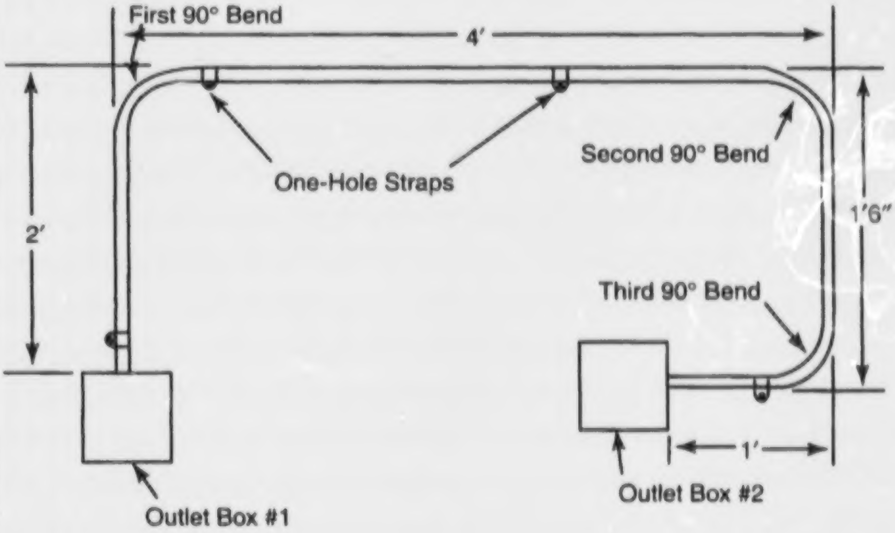
Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Mount the two outlet boxes as shown in Figure 1.

Figure 1


First 90° Bend
4′
One-Hole Straps
Second 90° Bend
2′
1′6″
Third 90° Bend
1′
Outlet Box #2
Outlet Box #1

☐ 4. Open knockout holes only where needed for tubing connectors.

☐ 5. Install one EMT connector in each outlet box.

☐ 6. Measure distance and tubing for first 90-degree bend shown in Figure 1.

☐ 7. Make bend.

☐ 8. Measure tubing for second 90-degree bend.

☐ 9. Make bend.

☐ 10. Install and fasten tubing as shown in Figure 1.

Note: Refer to NEC Article 358.30(B) regarding straps.

☐ 11. Measure distance and tubing for third 90-degree bend.

☐ 12. Bend tubing and install.

Note: If necessary, cut tubing to fit space. Be sure to wear eye protection when using hacksaw.

☐ 13. Return tools and materials to proper storage.

☐ 14. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 15

Job Sheet 6—Bend a Three-Point Saddle on One-Half-Inch EMT

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Conduit saddle proper height	______
• Center of saddle directly over obstruction	______
• Bends accurate	______
• Workmanship	______
• Compliance to *NEC*	

Basic Skills

Reading Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- 1/2-inch (16) EMT bender
- 10 feet of 1/2-inch (16) EMT
- Pouch tools
- 2-inch (53) O.D. pipe
- 2-inch (53) pipe straps
- Two 1900 boxes
- Two 1/2" (16) connectors
- Two 1/2" (16) one hole straps
- Eight #10 x 1" SMS
- Eye protection

Procedure

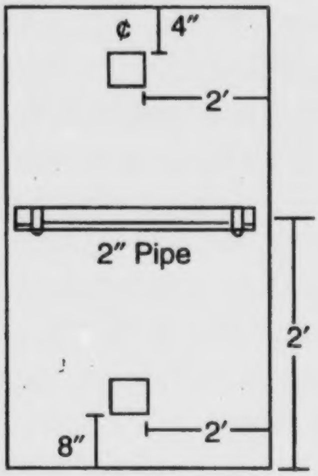
☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Put on eye protection.

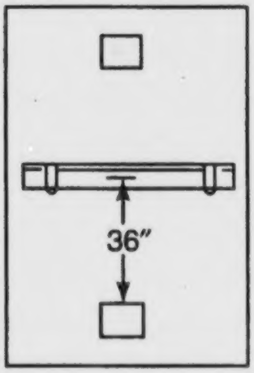
☐ 4. Mount the 2″ (53) pipe in the center of a 4′ x 8′ sheet of plywood, then mount the two 1900 boxes as shown in Figure 1.

Figure 1



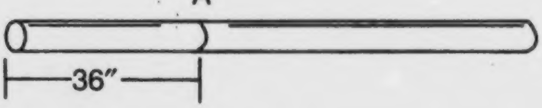
☐ 5. Measure from the bottom 1900 box to the center of the obstruction.

Figure 2



☐ 6. Mark this measurement (A) on the $^1/_2$″ (16) EMT.

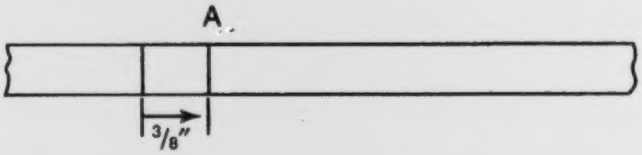
Figure 3



☐ 7. Measure the height of the obstruction. Move mark "A" ahead 3/16 of an inch for each inch of obstruction height. This becomes the center of the saddle.

Note: The obstruction is 2" high ($\frac{3}{16} \times 2 = \frac{6}{16} = \frac{3}{8}$) so mark "A" is moved ahead 3/8".

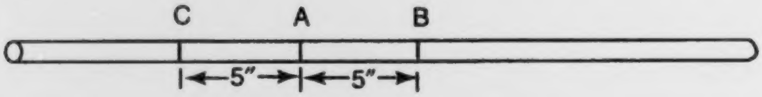
Figure 4



☐ 8. For each inch of obstruction height, multiply that amount by 2 1/2. This will give you distance "L" between marks "A" and "B" and between marks "A" and "C". Calculate distance "L" and mark "B" and "C" on EMT.

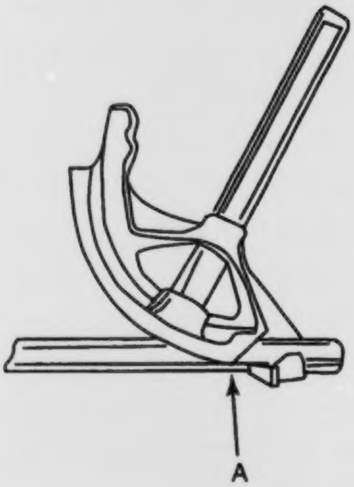
Note: 2 1/2 is a constant. In this case, the height is 2" (2 x 2 1/2 = 5), so distance "L" will be 5".

Figure 5



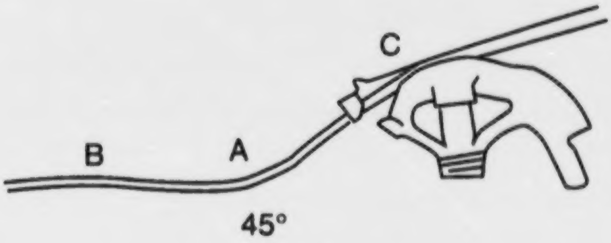
☐ 9. Place the bender rim notch or teardrop on mark "A" and pull to 45°.

Figure 6



☐ 10. Align mark "B" with the arrow on the bender and pull to 22 1/2°. Repeat this by making a 22 1/2° bend with mark "C" also at the arrow.

Figure 7



☐ 11. Install the conduit between the 1900 boxes.

☐ 12. Return tools and materials to proper storage.

☐ 13. Clean the work area.

Evaluator's Comments: ____________________

____

____

Objective 16

Job Sheet 7—Bend a Four-Point Saddle on One-Half-Inch EMT

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Pipe measurements correct	______
• Bends match	______
• Workmanship	______
• Compliance to *NEC*	______

Basic Skills

Reading

Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- 1/2-inch (16) EMT bender
- 10 feet of 1/2-inch (16) EMT
- Measuring tape
- 2″ x 4″ beam to be saddled
- Eye protection

Procedure

☐ 1. Observe safety rules throughout procedure.

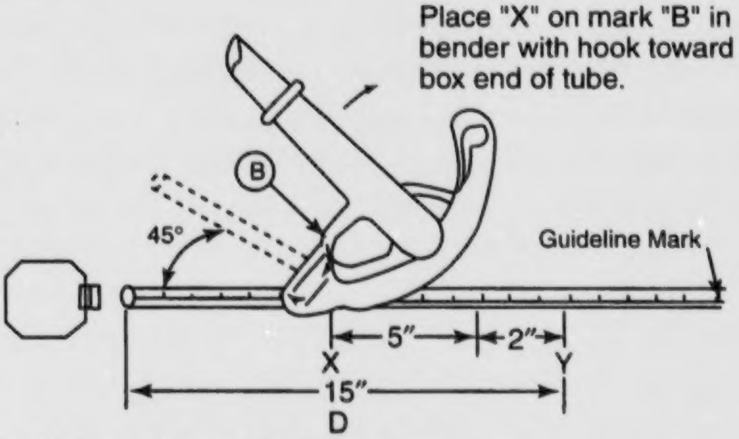
☐ 2. Check out proper tools and materials.

☐ 3. Put on eye protection.

☐ 4. Make a 4-inch offset bend (two 45° angles).

Note: Half the height of the offset (2 inches) plus 5 inches for 1/2-inch (16) conduit equals 7-inches.

Figure 1

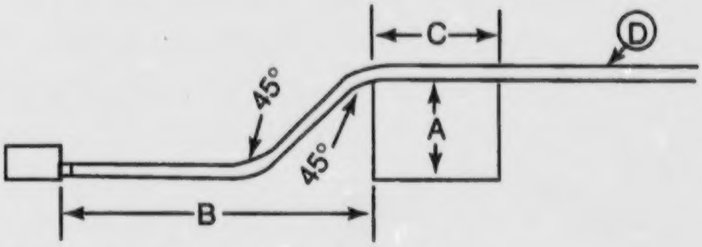

Place "X" on mark "B" in bender with hook toward box end of tube.
B
45°
Guideline Mark
5"
2"
X
Y
15"
D

Used with permission of Republic Steel Corporation.

☐ 5. Lay offset across beam to be saddled, and mark tubing at point D shown in Figure 2.

Figure 2

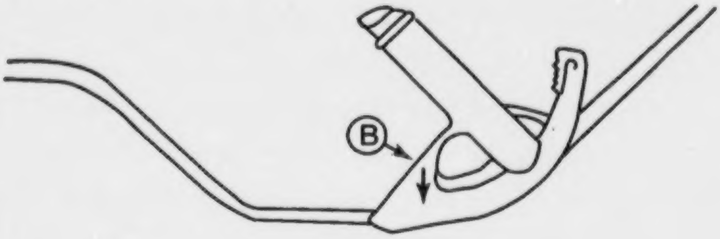
A = Height of Offset
B = Distance from Box to Offset
C = Width of Beam
D = Mark on Tube



Used with permission of Republic Steel Corporation.

☐ 6. Place tubing in bender, with bender point "B" at mark D, and bender hook toward finished part of offset.

Figure 3

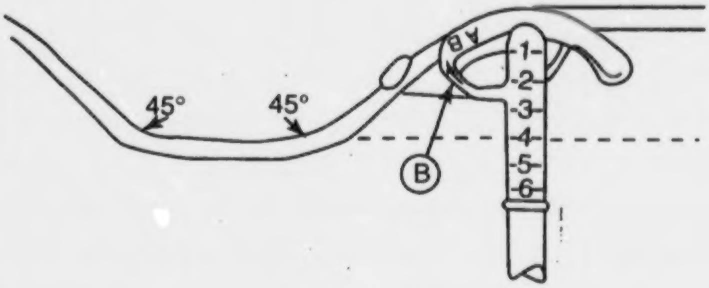


Used with permission of Republic Steel Corporation.

☐ 7. Make a 45-degree bend, and remove bender.

☐ 8. Complete this leg of saddle by sighting along edge of tubing to the 4-inch mark on bender as shown in Figure 4; mark tubing at 4-inch mark.

Figure 4



Used with permission of Republic Steel Corporation.

☐ 9. Remove bender, and place on tubing with bender point 'B" at 4-inch mark.

☐ 10. Make a 45-degree bend, and remove bender.

☐ 11. Place saddle over beam.

☐ 12. Return tools and materials to proper storage.

☐ 13. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 17

Job Sheet 8—Cut, Ream, Offset, and Install Connectors on One-Half-Inch PVC

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Measured pipe correctly	______
• Placed bends at correct points	______
• 45° bends obtained	
• Workmanship	______
• Compliance to *NEC*	

Basic Skills

Reading Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- 10 feet of $^{1}/_{2}$-inch (16) EMT
- Hacksaw
- PVC bender
- Skinning knife or other reaming tool
- Two $^{1}/_{2}$-inch (16) PVC connectors
- PVC cement
- Eye protection
- Measuring tape
- Marking pencil

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Put on eye protection.

☐ 4. Measure and mark a 24-inch segment of PVC.

☐ 5. Cut off the 24-inch piece, using a hacksaw.

Note: PVC is soft enough to cut with a wood handsaw without damaging the saw.

☐ 6. Using a knife or reaming tool, remove burrs from inside and outside of cut conduit.

Note: Cleaner must be used if conduit has dirt or oil on it.

☐ 7. Using PVC bender, bend two box offsets.

☐ 8. Install PVC connector on one end of cleaned piece of PVC.

- Apply PVC cement to **conduit** (male end of the splice) **only**.

  Note: Close PVC cement container immediately after use. When PVC cement is applied to the female end of a splice, the cement is forced back onto the conduit interior. When hard, it can damage insulation on wire and make pulling much more difficult.

- Quickly insert conduit into connector; twist the coupling one-quarter to one-half turn; let set for sixty seconds.

☐ 9. Repeat step 8 for other end of conduit.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 9

Job Sheet 1—Install an Overhead Raceway with Service Entrance Conductors to a Meter Base

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
• Practiced safety rules throughout procedure	______
• Pipe installed correctly	______
• Service head properly connected	______
• Marked conductors properly	______
• Correct length on conductors	______
• Mounted correctly	______
• Workmanship	______
• Compliance to *NEC*	

Basic Skills

Reading Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Flat blade screwdriver
- Lineman's pliers
- Hammer
- Knife
- Hacksaw
- Folding rule with sliding scale
- Service entrance cap (1 1/2″ clamp-on type)
- Three feet of 1 1/2″ rigid metal conduit (threaded on one end)
- Twelve feet of #2 copper TW (two 6′ pieces)
- Six feet of #4 copper
- Eye protection
- 3ϕ meter base

Procedure

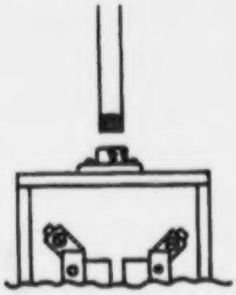
☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Put on eye protection.

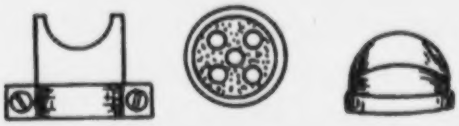
☐ 4. Screw threaded end of raceway into hub.

Figure 1



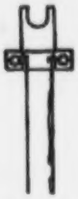
☐ 5. Remove cover and separator from weatherhead.

Figure 2



☐ 6. Clamp weatherhead base onto the end of the service raceway.

Figure 3



☐ 7. Install conductors in the raceway.

Note: Start at weatherhead end.

☐ 8. Connect the grounded conductor to the grounding lug.

Note: When possible, leave the grounded conductor long enough to connect to the disconnect equipment grounding bar.

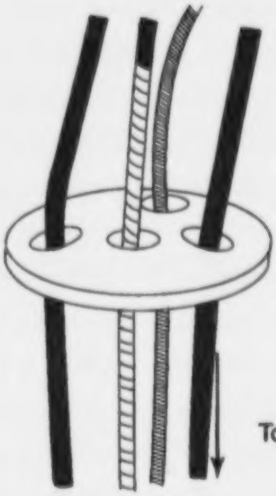
☐ 9. Remove 1″ to 1$^1/_2$″ of insulation from the ungrounded conductors and connect to the line lugs.

☐ 10. Knock out for outline holes in the entrance cap separator.

☐ 11. Put the grounded conductor through the center hole.

☐ 12. Put the ungrounded conductors through the side holes.

Figure 4



☐ 13. Gently start forming conductors so the separator will fit back into the base.

Note: Care must be taken while you are bending the curvature in the conductors to prevent damage to the plastic conductor separator.

☐ 14. Replace the service entrance cap cover.

☐ 15. Have instructor check your work.

☐ 16. Retain meter base for use in Job Sheet 2.

☐ 17. Clean work area and put away all un-needed equipment and materials.

Note: Review the equipment and materials list in Job Sheet 2 prior to completing Step 17.

Evaluator's Comments: ______________________________

____

____

Objective 10

Job Sheet 2—Conect a Meter Base Assembly To a Load Center or Panel

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	____
• Panel mounted correctly	____
• Nipple installed properly	____
• Conductors terminated	____
• Workmanship	____
• Compliance to *NEC*	____

Basic Skills

Reading Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Screwdriver
- Lineman's pliers
- Hammer
- Knife
- Level
- Rule
- Awl
- Meter base assembly from Job Sheet 1
- Two 1¼″ insulating bushings
- Four 1¼″ locknuts
- One 1¼″ reamed nipple long enough to connect meter base to distribution panel (Nipple, bushings, and locknuts may be larger than 1¼″ if conductor size or necessity mandates.)
- #4 copper (1 piece)
- #2 TW copper (3 pieces)
- Eight 1″ #12 metal tapping screws
- One 1½″ rigid conduit strap
- 2′ x 4′ mock-up wall or roughed in residential dwelling
- Eye protection
- One 100-amp 3-phase 3-wire SN load center

Procedure

☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Put on eye protection.

☐ 4. Mount the load center between studs with metal tapping screws.

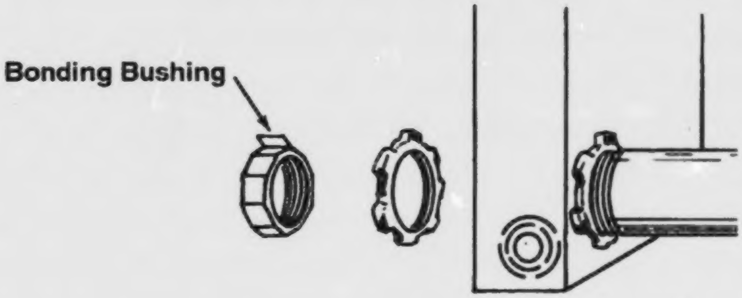
Note: Panel height should be adjusted so that knockouts will line up with meter base between 5′ and 6′. The utility company will give you their recommended height.

☐ 5. Remove the load center knockout that will align with the meter base at the correct height.

☐ 6. Install a nipple in the opening with a locknut on the back side of the load center and a locknut and bushing on the inside.

Note: Be sure that locknuts are installed tightly with their teeth into the metal. Also be sure to check local codes on bonding.

Figure 1



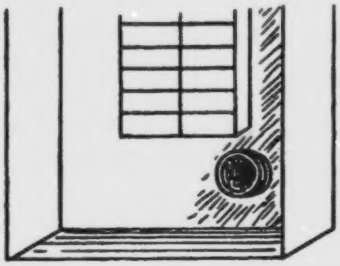
☐ 7. Remove the appropriate knockout from the meter base.

☐ 8. Put the back-up locknut for the metal base on the nipple.

☐ 9. Place the nipple through the meter base knockout and secure it loosely with one screw.

Note: Cut off excess nipple; leave only what is needed for the locknut and bushing.

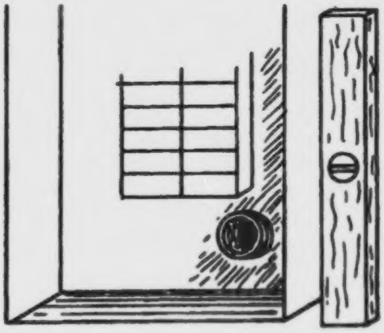
Figure 2



☐ 10. Install the internal locknut and bushing.

☐ 11. Place level on side of meter base and secure the base with mounting screws when leveled.

Figure 3



☐ 12. Put level on service raceway and secure the raceway with the strap when leveled.

☐ 13. Install a grounded conductor in a nipple and connect to the meter base and load center grounded lugs.

Note: Make all bends in conductors as square as possible while maintaining a radius equal to at least five times the diameter. Make sure you stay as far as possible from the load and the line lugs in your routing of the grounded conductors.

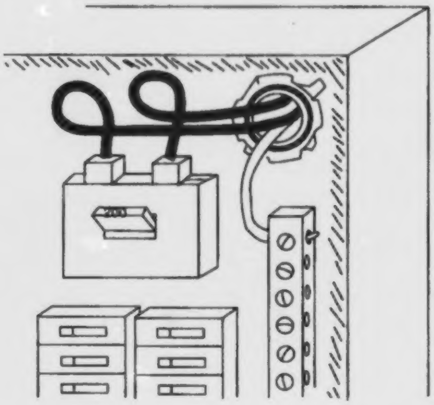
☐ 14. Install the ungrounded conductors in the nipple.

☐ 15. Strip about $1\frac{1}{2}''$ insulation from each of the ungrounded conductors, form them, and connect them to meter load lugs.

☐ 16. Form ungrounded conductors in load center.

☐ 17. Cut off excess and connect to the load center line lugs.

Figure 4



Note: The service system is still without a grounding electrode conductor. This conductor can originate at the load center or in the meter base. It can terminate at a cold water pipe or made electrode.

☐ 18. Have instructor check your work.

☐ 19. Return tools and materials to proper storage.

☐ 20. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 10

Focus Assignment 1—Analyze Utility Company Methods for Delivering Electrical Power

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Completed assignment	______
• Prepared for discussion	______

Basic Skills

Reading

Critical Thinking

Introduction

Are electrical power companies crazy? They generate power at a low voltage, transform it to a higher voltage for distribution, and then reduce it back to a lower voltage again at residential, commercial, or industrial properties.

Directions

Analyze and document the reason why they do this, and be prepared to present your conclusions in class.

Objective 11

Assignment Sheet 1—Draw a Three-Phase Wye-Delta Transformer

Name ______________________________ Overall Rating __________

Date ______________________________

Evaluation Criteria	Rating
• Correct transformer drawn	______
• Proper symbols used	______
• Neat, legible drawing	______

Basic Skills

Reading Writing

Directions

In the space provided below, draw a three-phase wye-delta transformer. The above criteria will be used to evaluate your performance.

Objective 12

Assignment Sheet 2—Locate and List Two Exceptions on Transformer Room Construction for Dry Type Transformers

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Proper use of *NEC* demonstrated	______
• Correct exceptions listed	______

Basic Skills

Reading

Directions

Using the *NEC*, locate and list two exceptions on transformer room construction for dry type transformers over 112.5 KVA. The above criteria will be used to evaluate your performance.

a. Exception No. _____

b. Exception No. _____

Objective 13

Assignment Sheet 3—Locate and List Two Exceptions Concerning Oil-Insulated Transformers

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Proper use of *NEC* demonstrated	______
• Correct exceptions listed	______

Basic Skills

Reading

Directions

Using the *NEC*, locate and list two exceptions to the requirement that oil-insulated transformers installed indoors require vaults. The above criteria will be used to evaluate your performance.

a. Article __________ Exception No. _____

b. Article __________ Exception No. _____

Objective 14

Assignment Sheet 4—Given Amperes, Calculate KVA on a Three-Phase System

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	**Rating**
• Correct conversions obtained	______
• Legible answers given	______

Basic Skills

Reading Mathematics

Directions

Convert the following amperes to KVA on a 480V three-phase system. The above criteria will be used to evaluate your performance.

a. 60.2 amps: ______________________ KVA

b. 120 amps: ______________________ KVA

c. 241 amps: ______________________ KVA

d. 602 amps: ______________________ KVA

Objective 15

Job Sheet 1—Test Transformer Turn Ratios

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Safety rules practiced throughout procedure	______
• Voltmeters and transformers connected correctly	______
• Voltmeter readings accurately recorded	______
• Transformer turn ratios calculated correctly	______
• Good workmanship	______
• Compliance to *NEC*	______

Basic Skills

Reading Mathematics Employability Critical Thinking

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Transformer, rated 480 to 120/240 volt
- Transformer, rated 240 to 24 volts
- Transformer, rated 120 to 24 volts
- Two voltmeters (one with 600-volt scale)
- Wire or test jumpers to connect transformers to power supply
- Single-phase power supply, 120/240-volt or 120/208-volt

Procedure

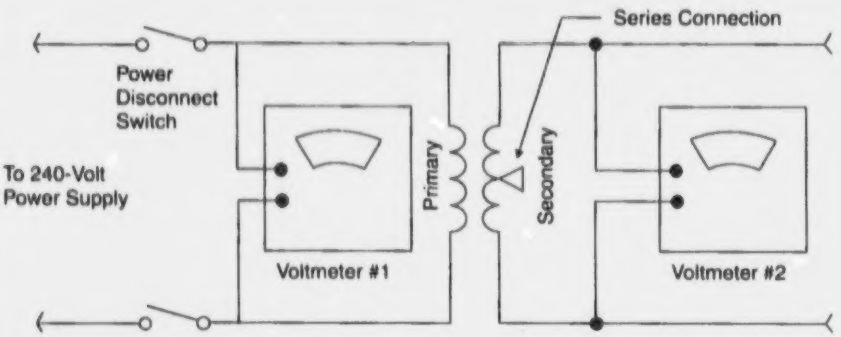
☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Connect both voltmeters to power supply after instructor's approval, and adjust needles until both read the same at near midscale.

☐ 4. Connect transformer as shown in Figure 1.

Figure 1


Series Connection
Power Disconnect Switch
To 240-Volt Power Supply
Primary
Secondary
Voltmeter #1
Voltmeter #2

☐ 5. Double-check connections for correctness.

☐ 6. Check to be sure that all leads are in the clear.

Note: Show work to instructor before proceeding.

☐ 7. Energize power supply.

☐ 8. Read both voltmeters.

☐ 9. Record voltmeter readings for Transformer #1.

VM #1 = ______________________________

VM #2 = ______________________________

☐ 10. Open power switch.

☐ 11. Calculate actual transformer turn ratio.

Note: Divide Voltmeter #2 reading by Voltmeter #1 reading to find the ratio. Show your work.

T#1 turn ratio = ______________________________

☐ 12. Compare calculated ratio with nameplate voltage ratio.

Note: Calculated ratio should match nameplate withing + 1 percent.

☐ 13. Test Transformer #2, using the same procedure as that used to test Transformer #1.

☐ 14. Record voltmeter readings for Transformer #2 and calculate turn ratio.

Note: Show your work.

VM #1 = ____________________

VM #2 = ____________________

T#2 turn ratio = ____________________

☐ 15. Test Transformer #3, using the same procedure as that used to test Transformer #1.

☐ 16. Record voltmeter readings for Transformer #3 and calculate turn ratio.

Note: Show your work.

VM #1 = ____________________

VM #2 = ____________________

T#3 turn ratio = ____________________

☐ 17. Return tools and materials to proper storage.

☐ 18. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 16

Job Sheet 2—Test Transformer Insulation Resistance

Name ______________________ Attempt Number ______

Date ______________________ Overall Rating ______

Evaluation Criteria	Rating
• Safety practiced throughout procedure	______
• Read instruments accurately	______
• Properly recorded instrument readings	______
• Good workmanship	______
• Compliance to *NEC*	______

Basic Skills

Reading Mathematics Employability Critical Thinking

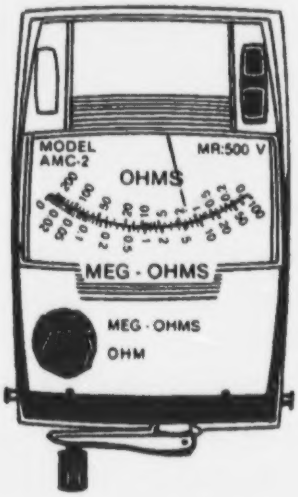
Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Three transformers (voltage not important; larger sizes if available)
- Test jumpers or wires to short windings
- Centigrade-scale thermometer
- Megger tester with leads (Figure 1)

Figure 1



Procedure

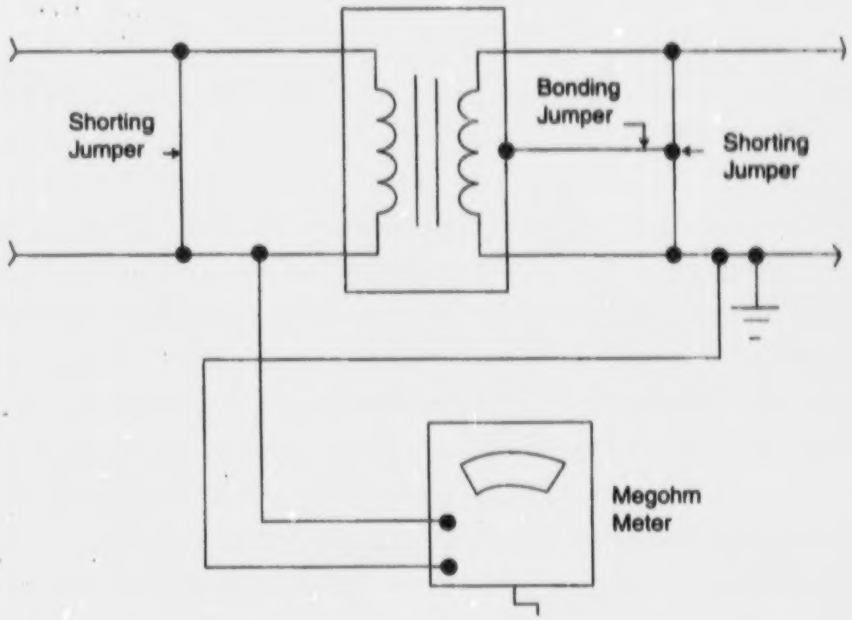
☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Test primary winding to secondary and ground.

a. Construct circuit as shown in Figure 2.

Figure 2



b. Short both windings.

c. Ground the secondary winding to transformer case.

d. As near as practicable, place thermometer to get the temperature of the interior of the windings.

e. After obtaining instructor approval, crank megger tester at about 120 rpm for sixty seconds or until needle settles down.

f. Read instrument while still cranking.

g. Stop cranking.

h. Record reading.

Megger reading = ______________________ Megohms

i. Check thermometer.

Note: Insulation resistance will decrease by 50 percent for every 10-degree centigrade rise in temperature, or double for every 10-degree centigrade drop in temperature.

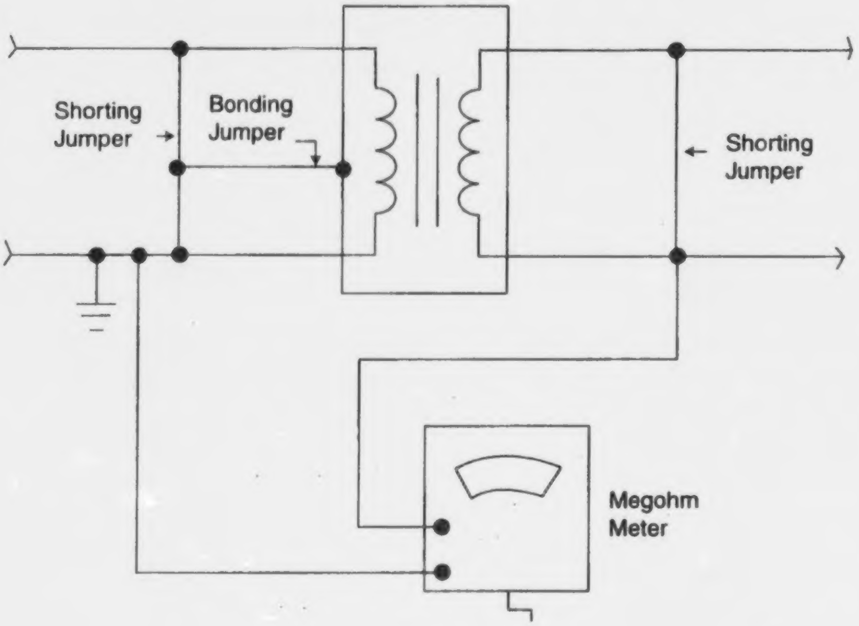
j. Record temperature.

Temperature = ______________________ °C

Note: Megohm readings become more meaningful when periodic tests are made on a piece of equipment, and then plotted on graph paper to make a curve.

☐ 4. Test secondary to primary and ground.

Figure 3



a. Short both windings.

b. Ground the primary winding to transformer case.

c. Make test as before on primary insulation.

Note: Follow Steps 3d through 3j.

Megger reading = ______________________ Megohms

Temperature = ______________________ °C

☐ 5. Repeat procedure on each remaining transformer.

a. Transformer #2

T2 megger reading = ______________________ Megohms

T2 Temperature = __________________________ °C

b. Transformer #3

T3 megger reading = ______________________ Megohms

T3Temperature = __________________________ °C

☐ 6. Return tools and materials to proper storage.

☐ 7. Clean the work area.

Evaluator's Comments: ______________________________________

____

____

Objective 17

Job Sheet 3—Connect Transformer Primary and Secondary Windings in a Delta-Wye Configuration

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Safety rules practiced throughout procedure	______
• Transformers properly connected in delta-wye	______
• Secured tight connections	______
• Obtained correct readings	______
• Good workmanship	______
• Compliance to *NEC*	

Basic Skills

Reading Mathematics Employability Critical Thinking

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Three-phase power supply, 240-volt

  Note: A three-phase 208-volt power supply will also serve satisfactorily.

- Three 5-ampere fuses in 240-volt circuit
- #14 wire, approximately 20 feet
- Wire nuts or bolts for connections
- Three transformers rated 240 to 120/240 (200 volt-amperes to 1 kilovolt-ampere capacity)
- Voltmeter with 600-volt scale
- One lamp and socket, 100 watt, 120 volt

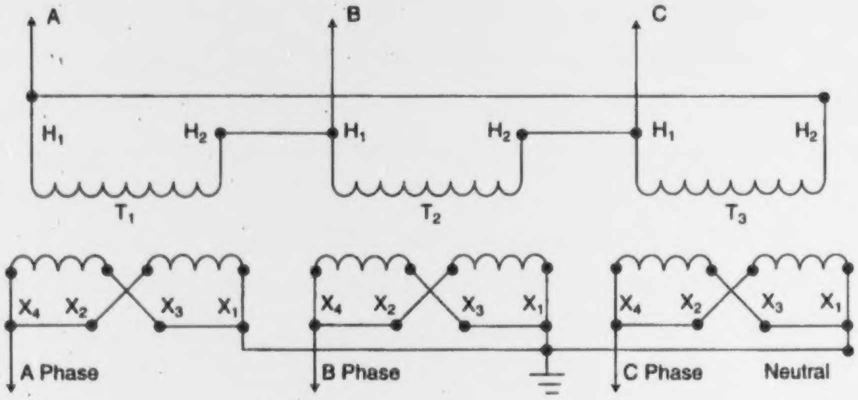
Procedure

☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Connect transformers in a delta primary to wye secondary configuration as shown in Figure 1.

Figure 1


A
B
C
H₁
H₂
H₁
H₂
H₁
H₂
T₁
T₂
T₃
X₄
X₂
X₃
X₁
X₄
X₂
X₃
X₁
X₄
X₂
X₃
X₁
A Phase
B Phase
C Phase
Neutral

☐ 4. Double-check all connections for correctness.

Note: Show connections to instructor before proceeding.

☐ 5. Energize 240-volt circuit.

☐ 6. Read and record low-side/secondary voltages.

Phase A to B ______________________

Phase A to C ______________________

Phase B to C ______________________

Phase A to neutral ______________________

Phase B to neutral ______________________

Phase C to neutral ______________________

☐ 7. Deenergize 240-volt circuit.

☐ 8. Connect 100-watt lamp to Phase A and neutral.

☐ 9. Reenergize 240-volt circuit.

☐ 10. Read and record voltages.

Phase A to neutral ______________________

Phase B to neutral ______________________

Phase C to neutral ______________________

☐ 11. Deenergize 240-volt circuit.

☐ 12. Connect the neutral to ground.

Note: An ungrounded neutral can shift when the load is unbalanced, causing low voltage at one point and high voltage at other points.

☐ 13. Read and record low-side/secondary voltages again.

Phase A to neutral ______________________

Phase B to neutral ______________________

Phase C to neutral ______________________

Phase A to B ______________________

Phase A to C ______________________

Phase B to C ______________________

☐ 14. Deenergize 240-volt circuit.

☐ 15. Disconnect T1 secondary leads from T2 and T3.

☐ 16. Connect terminal X4 of T1 to the neutral point.

☐ 17. Reenergize the circuit.

☐ 18. Read and record secondary voltages.

Phase A to B ______________________

Phase A to C ______________________

Phase B to C ______________________

Phase A to neutral ______________________

Phase B to neutral ______________________

Phase C to neutral ______________________

☐ 19. Return tools and materials to proper storage.

☐ 20. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 18

Job Sheet 4—Test and Compare Primary Apparent Power of a Transformer to Secondary Apparent Power

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
• Safety rules practiced throughout procedure	______
• All values correctly measured or calculated	______

Basic Skills

Reading Mathematics Employability Critical Thinking

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

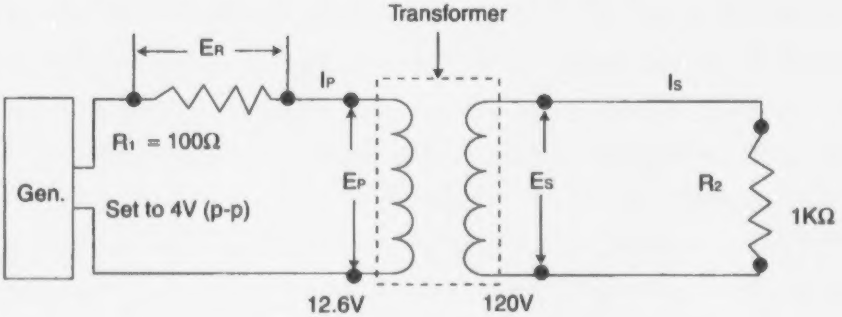
- 1KΩ Resistor
- 100Ω Resistor
- 120V/12.6V Transformer
- VOM/DMM
- Function generator
- Oscilloscope

Procedure

☐ 1. Measure resistor values: R_1 = ____________ R_2 = ____________

☐ 2. Set up the network shown below, using the measured resistor values.

Caution: Do not energize network before gaining instructor's approval.



☐ 3. Using the function generator, set the input voltage to 4V.

☐ 4. Measure E_P, E_S, and E_R.

E_P (rms) = ________ E_S (rms) = ________ E_R (rms) = ________

☐ 5. Using the measured resistor values, calculate:

$I_S = \frac{E_S}{R_2}$ I_S (rms) = ______________

$I_P = \frac{E_R}{R_1}$ I_P (rms) = ______________

☐ 6. Calculate the turn ratios:

$\frac{E_P}{E_S} = \frac{N_P}{N_S}$ ______________________

N = Number of turns

$\frac{I_P}{I_S} = \frac{N_S}{N_P}$ ______________________

☐ 7. Using the values of I_P, E_P, I_S, and E_S, calculate apparent power. (P=E/I)

P (primary) = _____________ P (secondary) = _____________

☐ 8. Have instructor evaluate your work.

☐ 9. Clean work area and return tools and equipment to proper storage.

Evaluator's Comments: ____

____

____

Objective 8

Assignment Sheet 1—Determine the Number of Conductors Allowed to be Added to an Existing Conduit

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Followed *NEC*	______
• Obtained correct answers	______

Basic Skills

Reading Writing

Directions

Using the steps listed in Objective 4 of the Information Sheet and the *NEC*, determine if additional conductors may be added to a conduit or if a new conduit is necessary. Show your calculations. The above criteria will be used to evaluate your performance.

a. An existing rigid metal 3/4" (21) conduit contains three #10 THW conductors; you need to add three more #10 THW conductors.

b. A 1/2" (16) type a, rigid PVC conduit contains three #12 THHN conductors. Will four more #12 THHN conductors be allowed?

c. A 1 1/2" (41) flexible metal conduit contains three 1/O THW conductors. Will three #6 THHN conductors be allowed.

d. A 1 1/2" (41) rigid metal conduit contains three 1/O THW conductors. Will three #6 THHN conductors be allowed.

Objective 9

Job Sheet 1—Rough In a Wood Framed Wall

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Safety rules practiced throughout procedure	_____
• Allowed for 5/8" Sheetrock	_____
• Made accurate wall measurements	_____
• Correctly fastened bar hanger to studs	_____
• Demonstrated good workmanship	_____
• Complied to *NEC*	_____

Basic Skills

Reading

Employability

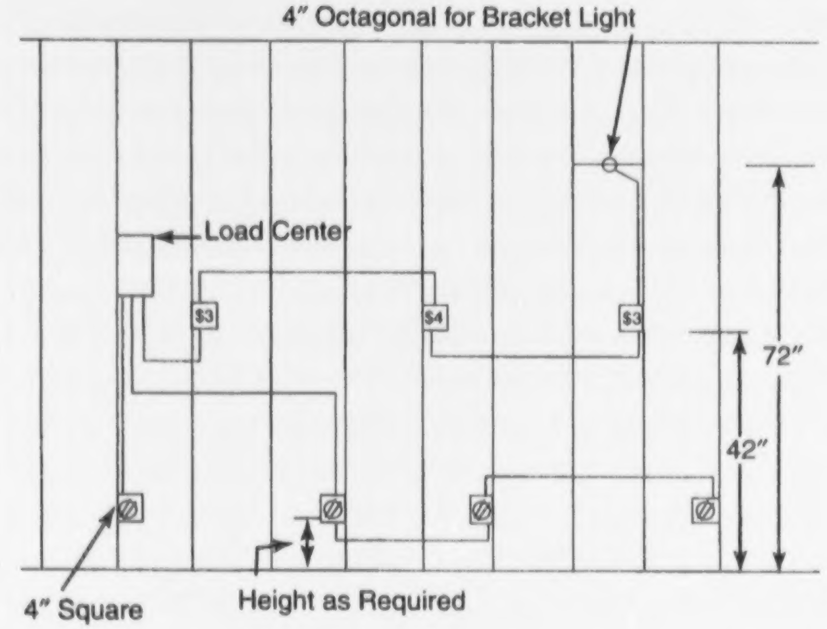
Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools, including hammer and tape
- 8-foot section of framed wall with 2" x 4" studs
- 5–Switch boxes 3" x 2 1/8" and 2 3/4" deep (75x50x70)
- 2–4" sq. boxes, 1 1/2" deep (100x38)
- 1–4" sq. combination device (single)
- 1–4" sq. combination device (two-device)
- 1-4" octagonal box, 1 1/2" deep (100x38)
- #8 mounting nails
- One expandable hanger bar
- One roll #12 THHN white
- One roll #12 THHN black
- One roll #12 THHN blue
- One roll #12 THHN red
- Forty feet of 1/2" (16) EMT
- Construction blueprint showing locations and other necessary information for box installation (Figure 1)

Figure 1



(see note below)

Procedure

☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

☐ 3. View blueprint for installation information to determine location of boxes.

Note: Mount boxes to allow for $^5/_8$-inch Sheetrock®.

☐ 4. Lay out job by marking studs where boxes are to be installed.

☐ 5. Place boxes on floor along wall where each is to be installed.

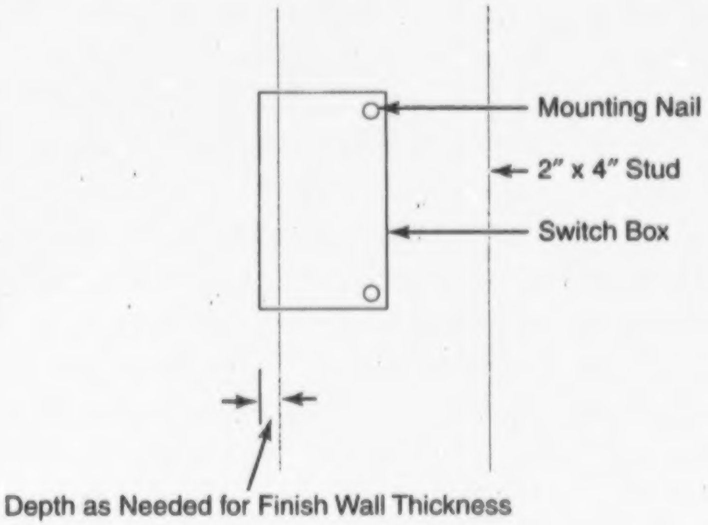
☐ 6. Measure heights, and mark studs for mounting boxes.

Note: A quick, accurate method of measuring for box installation is to cut a piece of conduit, lath, or other similar material to proper length from floor or floor plate to bottom of box. Boxes can be held on top of the measuring device and fastened to stud. This will prevent reading a rule for locating each box. A method often used in industry for height location of receptacle boxes is to set a hammer on the floor and position the box on top of the handle. The receptacle box can be fastened to the stud at that height.

☐ 7. Mount electrical boxes to studs at the locations and heights marked, with front edge of boxes parallel to face of stud and extended 1/2 inch to allow for 5/8-inch Sheetrock®.

Note: Four-inch square boxes are usually mounted with #8 or roofing nails, and switch boxes are usually mounted with #16 nails.

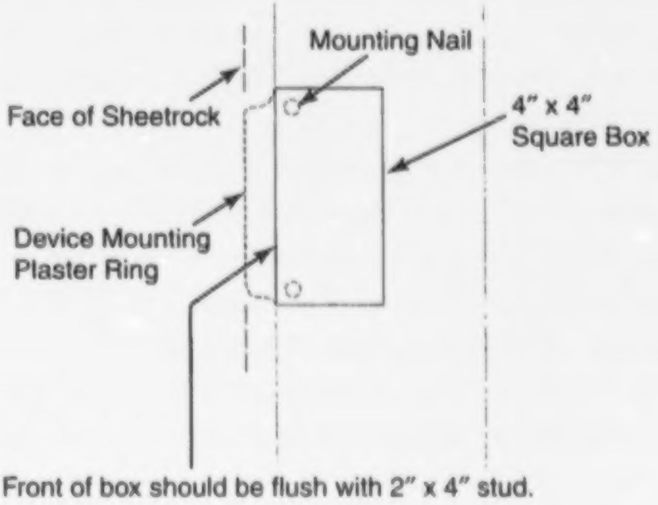
Figure 2


Mounting Nail
2" x 4" Stud
Switch Box
Depth as Needed for Finish Wall Thickness

☐ 8. Mount 4-inch square boxes to studs at the height and location as marked with front edge of box flush with face of stud. (Figure 3)

Note: Set four-inch square boxes 1/2 inch lower than switch boxes, device screws inside.

Figure 3


Mounting Nail
Face of Sheetrock
4" x 4" Square Box
Device Mounting Plaster Ring
Front of box should be flush with 2" x 4" stud.

☐ 9. Install octagonal outlet box for wall bracket light between two studs at location and height marked.

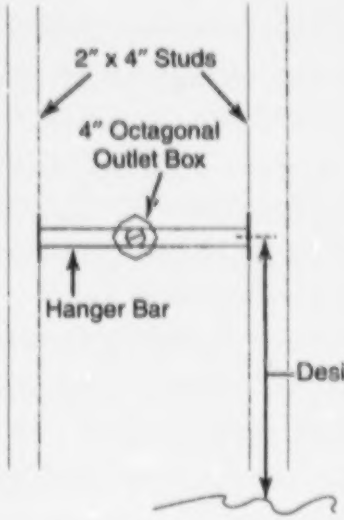
a. Spread expandable hanger bar to proper length to properly fit between studs.

b. Attach hanger bar to studs. (Figure 4)

Note: Hanger bars are usually fastened to studs with #8 nails.

c. Attach octagonal box to hanger-bar stud.

Figure 4


2" x 4" Studs
4" Octagonal Outlet Box
Hanger Bar
Designated Height

☐ 10. Rough in EMT runs.

☐ 11. Pull conductors and make up.

☐ 12. Return tools and materials to proper storage.

☐ 13. Clean work area.

Evaluator's Comments: ______________________________

____

____

Objective 10

Job Sheet 2—Install Outlet Boxes on Steel Rods

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Safety rules practiced throughout procedure	______
• Installed rods properly	______
• Mounted hanger correctly	______
• Fastened box properly	______
• Leveled EMT	______
• Connected box to EMT	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading

Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Stove bolt, $^{1}/_{4}$ inch by $^{1}/_{2}$ inch
- Three foot piece of 1/2-inch (16) EMT
- $^{1}/_{2}$-inch (16) EMT connector
- 4-inch square outlet box, $2^{1}/_{8}''$ deep (100x54)
- Two 3-foot pieces of $^{1}/_{4}$-inch rod
- Two rod-hanger clamps. Caddy Catalog #708-2-4 or equivalent
- Two conduit box clips, Caddy Catalog #4-1-2-4 or equivalent
- Pouch tools

Procedure

☐ 1. Observe safety rules throughout this procedure.

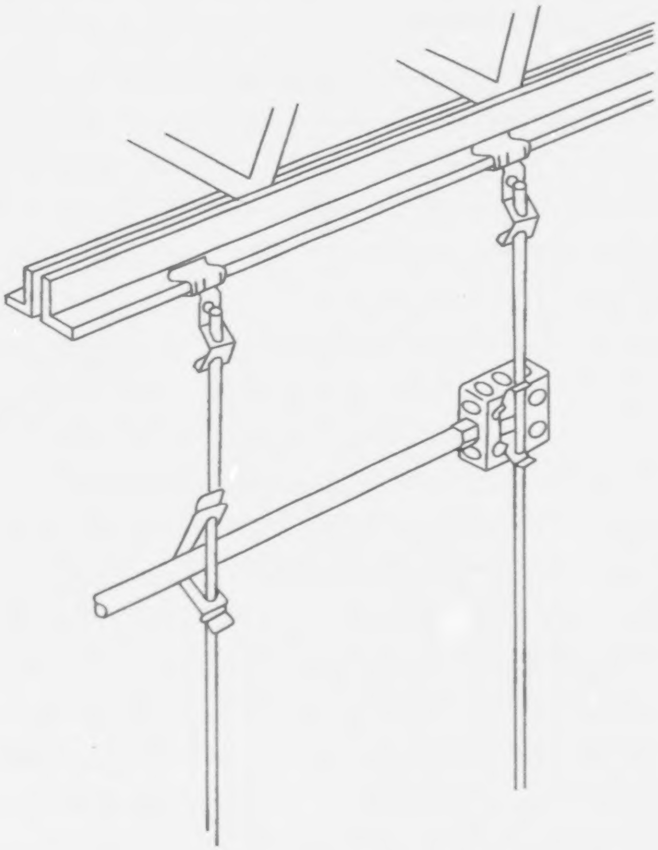
☐ 2. Check out proper tools and materials.

☐ 3. Install two $^{1}/_{4}$-inch rods in rod-hanger clamps.

☐ 4. Mount two rod-hanger clamps on suspended angle iron approximately 24 inches apart.

☐ 5. Install 1/2-inch (16) EMT in 4-inch (100) square box. (Figure 1)

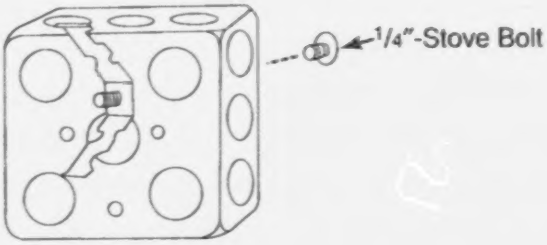
Figure 1



Used with permission of ERICO Products, Inc.

☐ 6. Fasten rod-hanger clip to square box. (Figure 2)

Figure 2

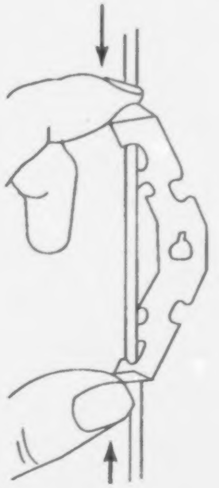


Used with permission of ERICO Products, Inc.

☐ 7. Mount box and EMT to the two 1/4-inch rods. (Figure 2)

☐ 8. Adjust to proper height. (Figure 3)

Figure 3



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Note: Have instructor evaluate your project.

☐ 9. Clean work area, and carefully dismantle your equipment. Return it to proper storage.

Evaluator's Comments: ______________________________

____

____

Objective 11

Job Sheet 3—Install Outlet Boxes on Steel studs Using Caddy Metal Stud Clips for Switch Boxes

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Safety rules practiced throughout procedure	______
• Mounted clip to box	______
• Mounted boxes to stud correctly	______
• Mounted MF clip to box	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Hammer
- 8-foot section of steel-stud wall
- Three electrical switch boxes, $2\frac{3}{4}$" (70) deep
- 4-inch square electrical box, $1\frac{1}{2}$" (100x38) deep
- Handy box, $1\frac{1}{8}$" (32) deep
- Metal stud clip, Caddy #MSB-625 or equivalent
- Four MF clips for switch boxes, Caddy #MF-625 or equivalent

Procedure

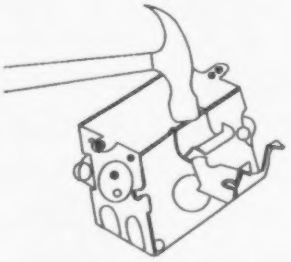
Note: Boxes may be mounted at non-designated places since intent of this job sheet is to acquaint students with box mounting methods when working with steel-stud walls.

☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Mount metal stud clip to switch box.

Figure 1



Used with permission of ERICO Products, Inc.

☐ 4. Mount box and clip to steel stud. (Figures 2 and 3)

Figure 2

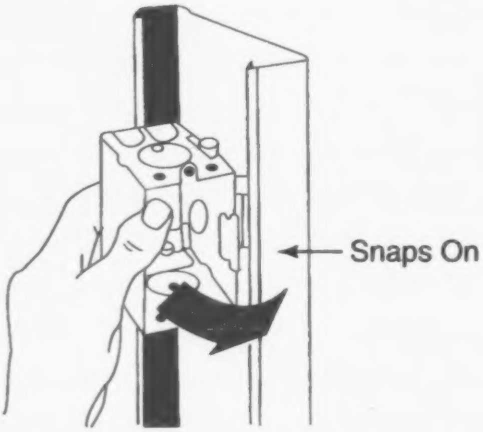


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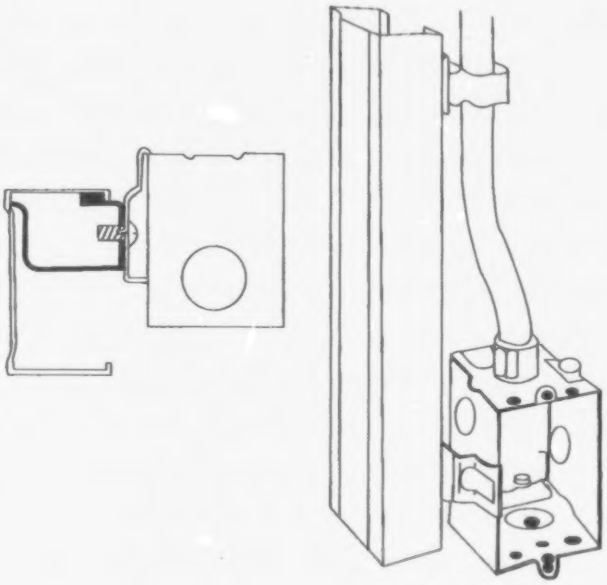
Figure 3



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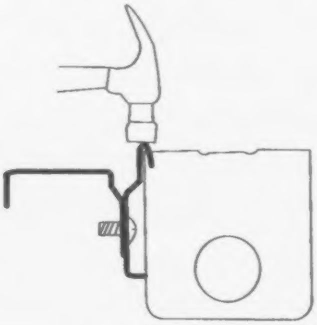
☐ 5. Mount one MF clip on each of the other boxes. (Figure 4)

Figure 4



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☐ 6. Mount clips and boxes to metal studs. (Figures 5 and 6)

Figure 5

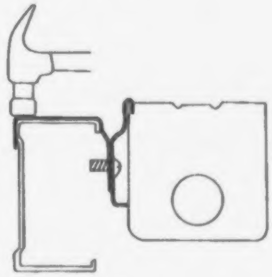

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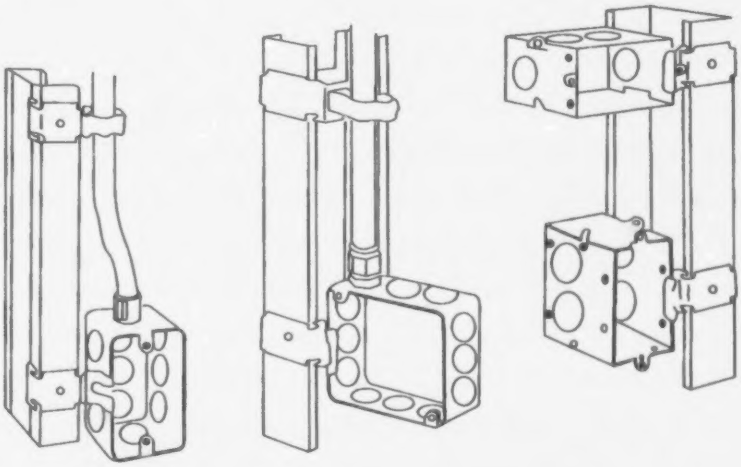
Figure 6



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☐ 7. Have instructor evaluate your work.

☐ 8. Clean work area, and carefully dismantle your equipment and return it to proper storage.

Evaluator's Comments: ______________________________

____

____

Objective 12

Job Sheet 4—Install Masonry Boxes in a Block Wall

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Safety rules practiced throughout procedure	______
• All pieces of EMT cut the same length (approx. 30")	______
• Installed connector in box properly	______
• Connected coupling properly	______
• Exact 90° bend made	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading

Employability

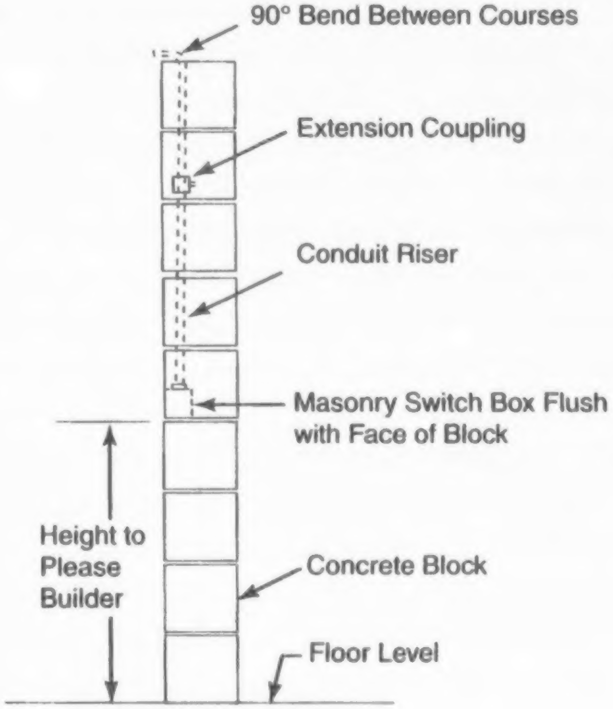
Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools
- Hacksaw
- Two masonry switch boxes, 3 1/2" (95x50x65) deep
- Two masonry two-gang boxes, 3 1/2" (95x50x90) deep
- 20 feet of 1/2-inch (16) EMT
- Four 1/2-inch (16) EMT setscrew or compression connectors
- Four 1/2-inch (16) EMT setscrew or compression connectors
- Conduit bender
- Blueprint such as Figure 1

Figure 1


90° Bend Between Courses
Extension Coupling
Conduit Riser
Masonry Switch Box Flush with Face of Block
Height to Please Builder
Concrete Block
Floor Level

Procedure

Note: This job must be done in cooperation with the masonry instructor because the electrical components are to be installed as the block wall is constructed.

☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Open 1/2-inch (16) knockout hole nearest to the back of box so that EMT will be in the hollow of the cement blocks.

Note: Masonry boxes generally have concentric $^1/_2$-inch (16) and $^3/_4$-inch (21) knockout punchings; exercise care to break out only the $^1/_2$-inch (16) part.

☐ 4. Cut eight pieces of $^1/_2$-inch (16) EMT, approximately 30 inches long.

Note: Cut all eight pieces exactly the same length.

☐ 5. Install $^1/_2$-inch (16) EMT connectors in each of the four masonry box knockout holes.

Note: If during knockout removal, the $^3/_4$-inch (21) punching breaks out instead of the $^1/_2$-inch (16) punching, see your instructor. You will need two $^3/_4$-inch (21) by $^1/_2$-inch (16) reducing washers for each $^3/_4$-inch (21) hole to properly install $^1/_2$-inch (16) EMT.

☐ 6. Install a 30-inch piece of EMT in each connector.

Note: The person laying the blocks must install each block down over the vertical conduit.

☐ 7. Deliver the made-up boxes to the block layer.

Note: The electrician and the block layer must work together to be sure that the boxes are installed in the proper locations, and correctly installed with the EMT extending upward in the wall. See Figure 1.

☐ 8. When the block wall reaches the desired height, install the masonry boxes, extending conduit upward.

☐ 9. Supervise the installation of the next layers of blocks until only a short portion of the conduit is visible above the wall.

Note: The block mason must raise the blocks above the height of the conduit, and then lower the next blocks over the conduit so that it extends upward through the hollow of the blocks.

☐ 10. Install 30-inch pieces of conduit equipped with couplings to increase the height for next layers of blocks.

Note: The conduit is extended upward 2 or 3 feet at a time as the height of the wall increases.

☐ 11. Make a 90-degree bend in the conduit when the wall and conduit reach required height.

Note: A 90-degree bend will allow the conduit to stick out of the wall between ccurses. This will prevent having to cut into the blocks.

☐ 12. Have the instructor evaluate your work.

☐ 13. Clean work area, and carefully dismantle equipment and return it to proper storage.

Evaluator's Comments: ____________________________________

____

____

Objective 10

Assignment Sheet 1—Locate Article in the *NEC* Concerning Lighting Requirements

Name ______________________ Overall Rating ________

Date ______________________

Evaluation Criteria	**Rating**
• Correct use of *NEC* demonstrated	______
• Correct answers obtained	______

Basic Skills

Reading

Directions

List *NEC* article numbers that pertain to the following lighting conditions. The above criteria will be used to evaluate your performance.

a. Autotransformers ______________________

b. Tap conductors ______________________

c. Emergency lighting switch requirements ______________________

d. Wet and damp locations ______________________

e. Transformer ratings ______________________

f. Track lighting ______________________

Objective 11

Job Sheet 1—Change a Two-Lamp Ballast in a Fluorescent Fixture

Name ______________________ Attempt Number ______

Date ______________________ Overall Rating ______

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Installed ballast properly	______
• Connections tight	______
• Installed lamps correctly	______
• Fixture works	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools
- Eight wire nuts
- Two-lamp ballast
- Eye protection

Procedure

☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Put on eye protection.

☐ 4. Disconnect the power.

☐ 5. Remove the lamps.

☐ 6. Remove the ballast cover from the fixture.

☐ 7. Cut wires 6" from ends of socket.

Note: Do not cut wires less than 6" as this will void the warranty.

☐ 8. Remove the old ballast.

☐ 9. Install the new ballast.

Note: Check the warranty date on the ballast. Most ballasts are under warranty for one year.

☐ 10. Re-connect conductors back by color.

☐ 11. Re-connect the power.

☐ 12. Install the ballast cover plate.

☐ 13. Install the lamps.

☐ 14. Apply power and check the fixture operation.

☐ 15. Return tools and materials to proper storage.

☐ 16. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 12

Job Sheet 2—Change Sockets in a Fluorescent Fixture

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Wired sockets correctly	______
• Connections tight	______
• Installed lamps correctly	______
• Fixture works	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools
- Eight two-pin fixture sockets
- Eye protection

Procedure

☐ 1. Observe safety rules throughout the procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Put on eye protection.

☐ 4. Disconnect the power.

☐ 5. Remove the lamps.

☐ 6. Remove the ballast cover from the fixture.

☐ 7. Remove the socket end plate.

☐ 8. Remove one socket at a time and replace with a new socket.

☐ 9. Install the socket end plate.

☐ 10. Re-connect the power.

☐ 11. Install the ballast cover plate.

☐ 12. Install the lamps.

☐ 13. Apply power and check fixture operation.

☐ 14. Return tools and materials to proper storage.

☐ 15. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 13

Job Sheet 3—Change an HID Ballast

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Voltages match	______
• Installed ballast correctly	______
• Fixture works	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading

Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools
- HID ballast
- 12 yellow wire nuts

Procedure

☐ 1. Observe safety rules throughout the procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Disconnect the power.

☐ 4. Remove the cover from the fixture.

☐ 5. Check the old ballast voltage to the new ballast.

☐ 6. Cut the old ballast wiring.

☐ 7. Remove the old ballast.

☐ 8. Install the new ballast.

☐ 9. Connect the new ballast.

☐ 10. Install the cover plate.

☐ 11. Apply power and check fixture operation.

☐ 12. Return tools and materials to proper storage.

☐ 13. Clean the work area.

Evaluator's Comments: ______________________________

Objective 14

Job Sheet 4—Change a Quartz Lamp

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Installed new lamp correctly	______
• Fixture works	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools
- Paper towels or clean rags
- Quartz lamp

Procedure

☐ 1. Observe safety rules throughout the procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Disconnect the power.

☐ 4. Open the cover to the fixture.

☐ 5. Remove the old lamp.

☐ 6. Install the new lamp using a paper towel or rag.

Note: Do not touch the bulb with your bare hand. Touching the bulb with an uncovered hand will decrease the life of the bulb.

☐ 7. Close the cover to the fixture.

☐ 8. Apply power and check fixture operation.

☐ 9. Return tools and materials to proper storage.

☐ 10. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 25

Assignment Sheet 1—Interpret Nameplate Information

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Listed correct information for both motors	_____
• Answered all questions	_____

Basic Skills

Reading

Critical Thinking

Directions

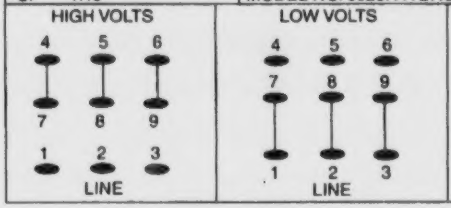
The industrial electrician must be able to interpret motor nameplate information in order to be able to service and repair an electric motor. Use the information on motor nameplate samples A and B below to answer the following questions. The above criteria will be used to evaluate your performance.

See reverse side for nameplates and questions.

Assignment Sheet 1

A.

WATTS INDUCTION MOTOR COMPANY		
HP 30	PH 3	HZ 60
RPM 1760	VOLTS 230/460	AMPS 64/33
FRAME 284T	DUTY CONT. @40°C	INSL CLASS B
KVA CODE G EFF .88	DRIVE SHAFT BRG. 6309 C.3	
NEMA DESIGN B	OPP. OR. SHAFT BRG. 6207 C.3	
ENCL TYPE TEFC	SERIAL NO. D785516	
SF 1.15	MODEL NO. 0525H4TBHC	



ADDITIONAL INFORMATION

B.

ABCXYZ INDUCTION MOTOR COMPANY					
NEMA DES 8	PHASE 3	INS CL F	HZ 60	KVA CODE F	SERIAL 7621
HORSE POWER 50	RPM 1670		SF 1.15		AMB 45°C
VOLTS 460	FRAME 324T				DUTY 24
AMPS. W/O CAP			MODEL TBFC		
AMPS WITH CAP 25			MAX. CAP 10.5 KVAR		
USER/CAT NUMBER			FL EFF 90°		
MOTOR STYLE					
DRIVE/LOWER BRG					
OPP.DRIVE/UPPER BRG					
ADDITIONAL INFORMATION					

		Motor "A"	Motor "B"
a.	What is the horsepower of each motor?		
b.	Is each a single-phase or three-phase motor?		
c.	At how many revolutions per minute does each motor operate?		
d.	What is the recommended voltage to which each motor should be connected?		
e.	How long is each motor designed to operate?		
f.	Under what temperature will each motor operate?		
g.	What type of overload protection does each motor have?		
h.	What is the identification number of each motor?		
i.	At how many cycles per second does each motor operate?		
j.	What is the type of each motor?		
k.	What type of current does each motor use?		
l.	What is the rated full load current of each motor?		
m.	What is the service factor of each motor?		

Objective 26

Assignment Sheet 2—Describe Remedies for Common Motor Problems

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Correct answers given	______
• Adequate number of alternative possibilities listed	______

Basic Skills

Reading Writing Critical Thinking

Directions

The industrial electrician must be able to determine causes and remedy common motor problems. In the following situations, the problems are stated. List possible solutions for each problem. The above criteria will be used to evaluate your performance.

a. Motor fails to start— ______________________________

____

____

____

____

____

____

____

____

____

____

____

Problems continue on next page.

b. Motor is overheating— ____________________

c. Motor is excessively noisy— ____________________

d. Motor bearings are overheating— ____________________

Objective 27

Assignment Sheet 3—Use the *National Electrical Code* to Answer Questions About Motor Control Circuits

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	**Rating**
• Demonstrated proper use of the *NEC*	______
• Gave correct answers	______

Basic Skills

Reading

Directions

The industrial electrician must be able to interpret and apply the *National Electrical Code* by properly wiring all motor control circuits according to information found in Article 430. Use the *National Electrical Code* to answer the following questions. The above criteria will be used to evaluate your performance.

a. State the section of the *National Electrical Code* that deals with overcurrent protection.

____

b. List two exceptions for conductor protection in motor control circuits.

1. ____

2. ____

c. Is a transformer used to step down voltage for motor control circuits exempt from Article 430?

____

d. Describe the *National Electrical Code* requirements for protecting control conductors.

____

e. State the time when motor control circuits must be disconnected.

____

f. Define a motor control circuit.

____

____

g. State procedures for protecting conductors in control circuits.

____

h. Define "in sight" as it applies to motors and controllers.

____

____

Objective 28

Assignment Sheet 4—Distinguish Between Motor Starters and Contactors

Name ______________________ Overall Rating __________

Date ______________________

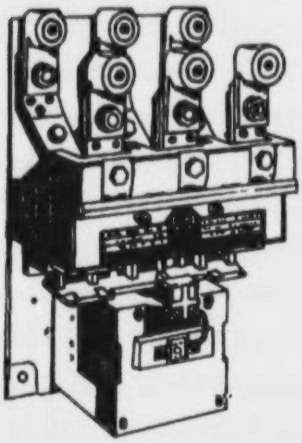
Evaluation Criteria	**Rating**
• Illustrations correctly identified	______
• Correct answers given to questions	______

Basic Skills

Reading Writing Critical Thinking

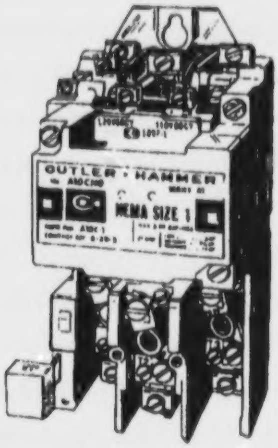
Directions

When servicing existing equipment, an electrician must be able to identify at a glance a motor starter or a contactor. Contactors never have thermal overload (heaters), reset buttons, or overload contacts. Look at the following pictures. Label each "contactor" or "motor starter", then answer the questions that follow. The above criteria will be used to evaluate your performance.



a. ______________________

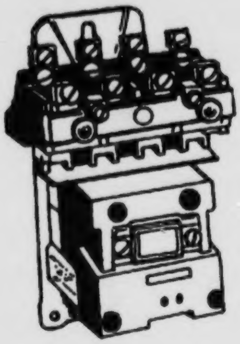
Adapted with permission of Allen-Bradley, a Rockwell International Company, Milwaukee, Wisconsin.



b. ______________________

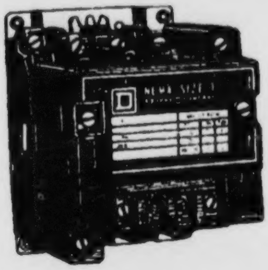
Adapted with permission of Cutler-Hammer Products/Eaton Corporation.

Assignment Sheet 4



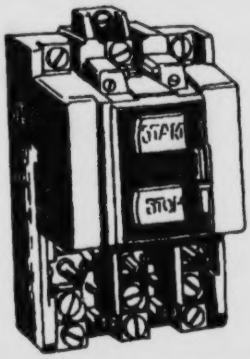
c. ____________________

Adapted with permission of Allen-Bradley, a Rockwell International Company, Milwaukee, Wisconsin.



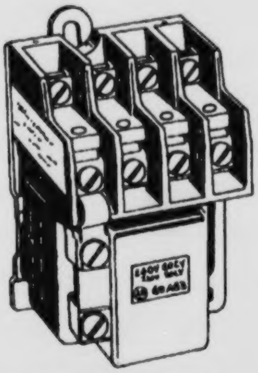
d. ____________________

Courtesy of Square D Company.



e. ____________________

Adapted with permission of Cutler-Hammer Products/Eaton Corporation.



f. ____________________

Adapted with permission of Allen-Bradley, a Rockwell International Company, Milwaukee, Wisconsin.

g. Which items did you recognize as being contactors? ____________

Explain why you selected these items as contactors. ____________

____

____

____

h. Which items did you recognize as being motor starters? ____________

Explain why you selected these items as motor starters. ______________

____

____

____

Objective 29

Assignment Sheet 5—Answer Questions About Uses of Contactors and Motor Starters

Name ______________________________ Overall Rating __________

Date ______________________________

Evaluation Criteria	**Rating**
• Correct answers given	______
• Answered all questions	______

Basic Skills

Reading

Directions

An industrial electrician must be able to select a motor starter or contactor according to its correct use. Contactors are used to make and break an electrical power circuit. Motor starters are used to make and break a motor's power circuit. Complete each of the following questions about motor starters and contactors and their uses. The above criteria will be used to evaluate your performance.

a. Which of the following lists contains contactor parts and which contains motor starter parts? Write "contactor" or "motor starter" in the blank above the correct column.

1. ____________________

Line terminals
Load terminals
Power contacts
Coil
Holding contacts
Overload contact
Reset button
Thermal overloads (heaters)

2. ____________________

Line terminals
Load terminals
Coil
Holding contacts
Power contacts

b. Name five uses of magnetic contactors.

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________

c. List four uses of magnetic motor starters.

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

d. State three reasons why a contactor cannot be used to control a motor.

1. ______________________________

____

2. ______________________________

____

3. ______________________________

____

Objective 30

Job Sheet 1—Disassemble, Inspect, and Clean a Motor

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Disassembled and cleaned motor correctly	______
• Reassembled motor correctly	______
• Motor runs	______
• Demonstrated good workmanship	______

Basic Skills

Reading

Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Split-phase motor
- Screwdriver set
- Combination wrench set
- Center punch
- Ball peen hammer
- Soft-faced hammer
- Small socket wrench set
- Motor cleaning fluid
- Clean shop towel
- Compressed air
- Eye protection
- Lead marking material
- Polishing cloth
- Gear puller
- Machine oil

Procedure

☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Put on eye protection.

☐ 4. Check to be sure that electrical power is disconnected and locked open.

☐ 5. Remove motor from equipment, if necessary, and mark leads.

☐ 6. Clean outer surface of motor.

☐ 7. Disconnect wires at motor terminals.

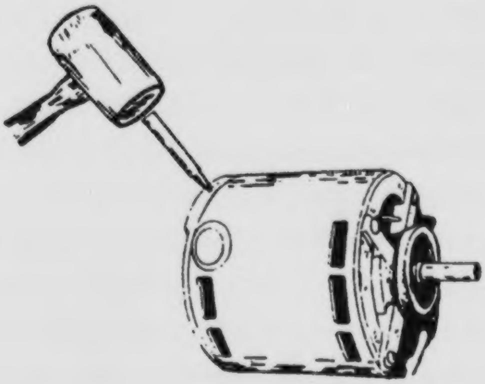
Note: Label wire positions by number or color on motor terminals, or draw a diagram.

☐ 8. Remove motor pulley.

☐ 9. Mark end bells to keep them in their proper places.

- Using center punch, place one mark on pulley end bell and two marks on opposite end bell.
- Mark housing in the same way.

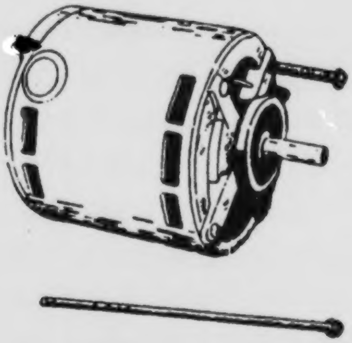
Figure 1



☐ 10. Check motor for end play.

☐ 11. Remove bolts holding end bells.

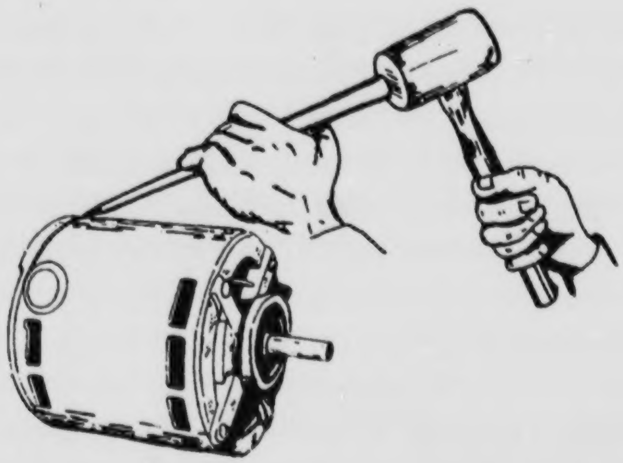
Figure 2



☐ 12. Polish shaft ends for easy removal.

☐ 13. Use soft-faced hammer and punch to tap end bells loose.

Figure 3



☐ 14. Remove end bell that does not contain starting switch.

☐ 15. Remove rotor.

Note: Observe position and number of thrust washers as you remove the rotor.

☐ 16. Remove end bell containing starting switch.

Caution: Do not attempt to remove the stator.

☐ 17. Clean motor with compressed air.

☐ 18. Check centrifugal mechanism and starting switch.

☐ 19. Clean outside of motor with special cleaning fluid.

☐ 20. Check stator coils, insulation, and coil supports.

☐ 21. Clean bearings, and make sure that wicking is in place and oiled.

Caution: Do not clean ball bearings with compressed air.

☐ 22. Reinstall end bell containing starting switch.

☐ 23. Insert rotor, making sure that thrust washers are in place.

Note: Place a drop of oil on the bearing part of the shaft.

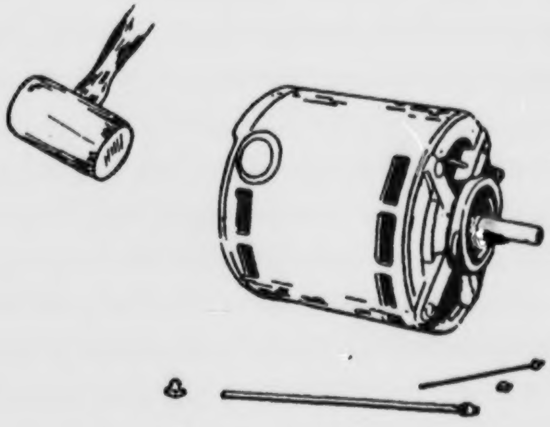
☐ 24. Reinstall second end bell.

☐ 25. Visually inspect rotor and stator alignment.

☐ 26. Check position of end bells to center punch marks.

☐ 27. Use soft-faced hammer to tap end bells into place.

Figure 4



☐ 28. Insert end-bell bolts; tighten.

☐ 29. Turn shaft by hand, and check for end play.

Note: If shaft is tight, end bells may not be in proper alignment, or the wicking may be between the bearing and the shaft.

☐ 30. Connect temporary leads; test motor.

☐ 31. Return tools and materials to proper storage.

☐ 32. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 31

Job Sheet 2—Identify Run, Common, and Start Terminals on Hermetically Sealed Motors

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Motor 1 terminals correctly identified	______
• Motor 2 terminals correctly identified	______
• Motor 3 terminals correctly identified	______
• Demonstrated good workmanship	______

Basic Skills

Reading Employability Science

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Ohmmeter with leads and test clips
- Three hermetically sealed compressor units
- Paper to sketch terminals and record ohm readings
- Pen or pencil

Procedure

☐ 1. Observe safety rules throughout this procedure.

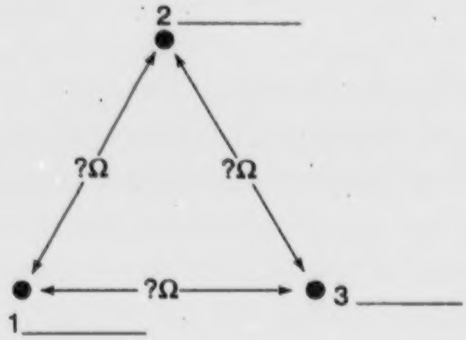
☐ 2. Check out proper tools and materials.

☐ 3. Clean terminals to ensure good connections.

Note: The terminals on most units are *not* identified.

☐ 4. Draw sketch of compressor unit electrical terminals as shown in Figure 1.

Figure 1



☐ 5. Test and record ohms between terminals 1 and 2.

1 to 2 = ______________________ ohms

☐ 6. Test and record ohms between terminals 2 and 3.

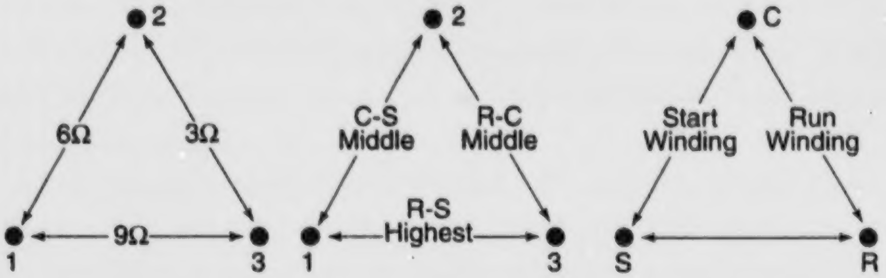
2 to 3 = ______________________ ohms

☐ 7. Test and record ohms between terminals 1 and 3.

1 to 3 = ______________________ ohms

☐ 8. Analyze readings and label sketch as in Figures 2 through 4.

Figure 2



Note: The run winding has larger wire, so it has the lowest resistance (R is common to highest and lowest readings). The start winding has smaller wire and more terminals, so it has a higher reading (S is common to highest and middle readings). The combined resistance of run and start windings is measured between R and S, so it gives the highest reading (C is common to middle and lowest readings).

☐ 9. Repeat steps 3 through 6 on at least two more compressor units.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 32

Job Sheet 3—Test Capacitors With An Ohmmeter

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Capacitor 1 accurately tested	______
• Capacitor 2 accurately tested	______
• Capacitor 3 accurately tested	______
• Capacitor 4 accurately tested	______
• Capacitor 5 accurately tested	______
• Capacitor 6 accurately tested	______

Basic Skills

Reading

Employability

Science

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- 1,000-ohm ohmmeter with leads
- Six start or run capacitors with clean terminals
- Bleeder resistor with attached leads, approximately 75 ohms

  Note: The TIF-CT-660 capacitor tester has proven to be a good, inexpensive tool for these tests; however, ohmeters may also be used

- Eye protection

Procedure

☐ 1. Observe safety rules throughout this procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Put on eye protection.

☐ 4. Apply bleeder resistor across capacitor terminals long enough to be sure that capacitor is discharged.

☐ 5. Set ohmmeter on R x 1,000 range.

☐ 6. Set ohmmeter leads and zero instrument.

☐ 7. Test for ground on run capacitors.

- Connect one ohmmeter lead to case.
- Touch other lead to capacitor terminal.

  Note: If indicator moves toward zero, capacitor is probably bad and should be discarded. No movement of indicator indicates that unit is not grounded.

☐ 8. Test for open and charging ability.

- Discharge capacitor completely.
- Connect one lead to one capacitor terminal.

  Note: Make a good connection.

- While watching ohmmeter, firmly contact other capacitor terminal with second lead.

  Note: If the capacitor is good, the ohmmeter indicator will make a sudden move toward zero ohms, then stop and move less rapidly to the high resistance end of scale as the capacitor takes a charge from the voltage applied by the ohmmeter.

- Discharge capacitor and repeat test several times.

  Note: If capacitor is open, the ohmmeter indicator will not move. If capacitor is shorted, the instrument will indicate zero or low resistance. If this occurs, discard the unit.

☐ 9. Repeat test procedure on each capacitor.

Note: Destroy bad units to prevent their reinstallation.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ____________________

____

____

Objective 33

Job Sheet 4—Wire a Three-Phase Motor for Dual Voltages

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Made proper low-voltage connection	______
• Made proper high-voltage connection	______
• Reversed motor's rotation correctly	______
• Demonstrated good workmanship	______

Basic Skills

Reading

Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Dual-voltage motor
- Pouch tools
- Wire nuts
- Wire markers

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Open motor lead connection box.

☐ 4. Separate leads.

☐ 5. Check motor name plate for low-voltage connections.

☐ 6. Hook up leads as shown on motor plate.

☐ 7. Label leads that would go to L1, L2, and L3.

Note: Tell instructor the voltage you wired the motor for; have instructor inspect your work.

☐ 8. Disconnect all leads.

☐ 9. Check motor name plate for high-voltage connections.

☐ 10. Hook up leads as shown on motor name plate.

☐ 11. Mark leads that would go to L1, L2, and L3.

Note: Tell the instructor what voltage you set the motor up for; have instructor inspect your work.

☐ 12. Reverse the motor's rotation.

☐ 13. Return tools and materials to proper storage.

☐ 14. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 34

Job Sheet 5—Perform Maintenance on a Magnetic Contactor

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Contacts operable	______
• Armature clean	______
• Unit operates	______
• Demonstrated good workmanship	______

Basic Skills

Reading Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Contactor or motor starter
- Screwdriver
- Needle-nosed pliers
- New magnetic coil
- Wire brush

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Remove the four screws holding the coil cover to expose the coil and yoke.

☐ 4. Carefully remove the coil and magnet yoke, together, from the contact carrier.

☐ 5. Remove the yoke retainer.

Note: This would lead to the removal of the yoke which allows the coil to be removed.

☐ 6. Remove the contact carrier with movable contacts, armature, and retainer springs from the base to expose the stationary parts of the conductor.

☐ 7. Remove hood cover to expose the stationary contacts carried by the mounting plate, and arc quencher on the reverse side of the hood cover.

Note: The mounting plate provides a base on which to attach the stationary contacts and makes it possible to mount the contactor to an electrical panel.

☐ 8. To reassemble, guide the hood cover into proper position using the cover screws.

☐ 9. Slide the contact carrier back into position along with the movable contacts, armature, and retainer springs.

☐ 10. Replace the magnet yoke into the square space in the coil.

☐ 11. Anchor the yoke and coil using the yoke retainer.

☐ 12. Slide the coil and yoke assembly into the movable contact carrier.

☐ 13. Replace the coil cover and tighten with screws.

☐ 14. Tighten the hood cover screws.

☐ 15. Have instructor check your work.

☐ 16. Return tools and materials to proper storage.

☐ 17. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 7

Assignment Sheet 1—Construct a Basic Ladder Diagram

Name ______________________ Overall Rating __________

Date ______________________

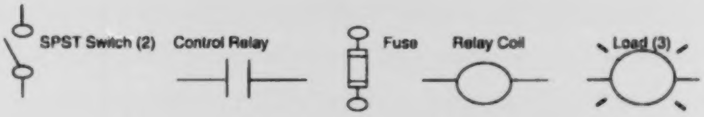
Evaluation Criteria	Rating
• Diagram legibly drawn	______
• All components correctly labeled	______
• Directions followed exactly	______

Basic Skills

Reading Writing

Directions

The electrical technician must be able to draw and read ladder diagrams to facilitate troubleshooting procedures. Using the graphic symbols provided below, draw, label, and reference ladder diagram with the following components; 120-VAC fused power supply, three loads, two single-pole single-throw (SPST) switches, and one control relay with a line voltage coil. Each load is to be a parallel circuit. Control two loads with the relay, one load with an SPST switch, and the relay coil with an SPST switch. The above criteria will be used to evaluate your performance. Draw your diagram on the back side of this page.



Objective 8

Assignment Sheet 2—Identify Electrical Symbols in a Wiring Diagram

Name ______________________________ Overall Rating __________

Date ______________________________

Evaluation Criteria **Rating**

- Correct answers given ______
- Legible handwriting ______

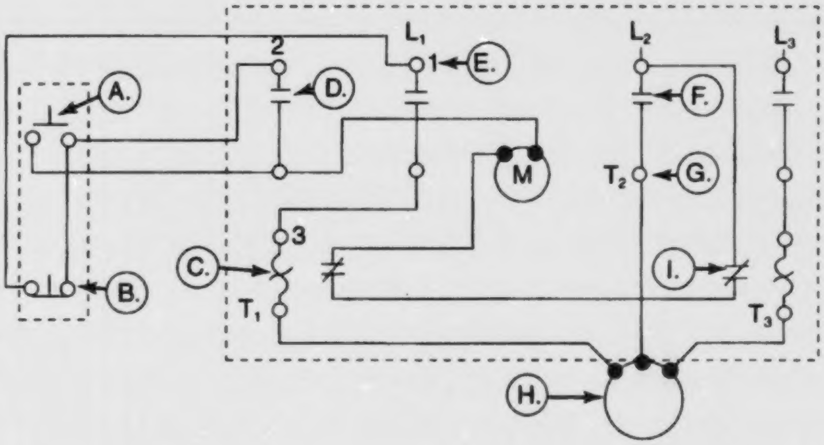
Basic Skills

Reading Writing

Directions

The electrical technician must be able to identify electrical symbols in a wiring diagram in order to recognize all component parts in a device or circuit. Identify the electrical symbols used in the wiring diagram illustrated below. Write the answers in the blanks on the next page. The above criteria will be used to evaluate your performance.

Line and control wiring terminal
Normally closed push button (stop)
Three-phase motor
Overload device switch
Normally open push button (start)
T2 motor lead terminal
Auxiliary contact
Thermal overload relay
Main contact



a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

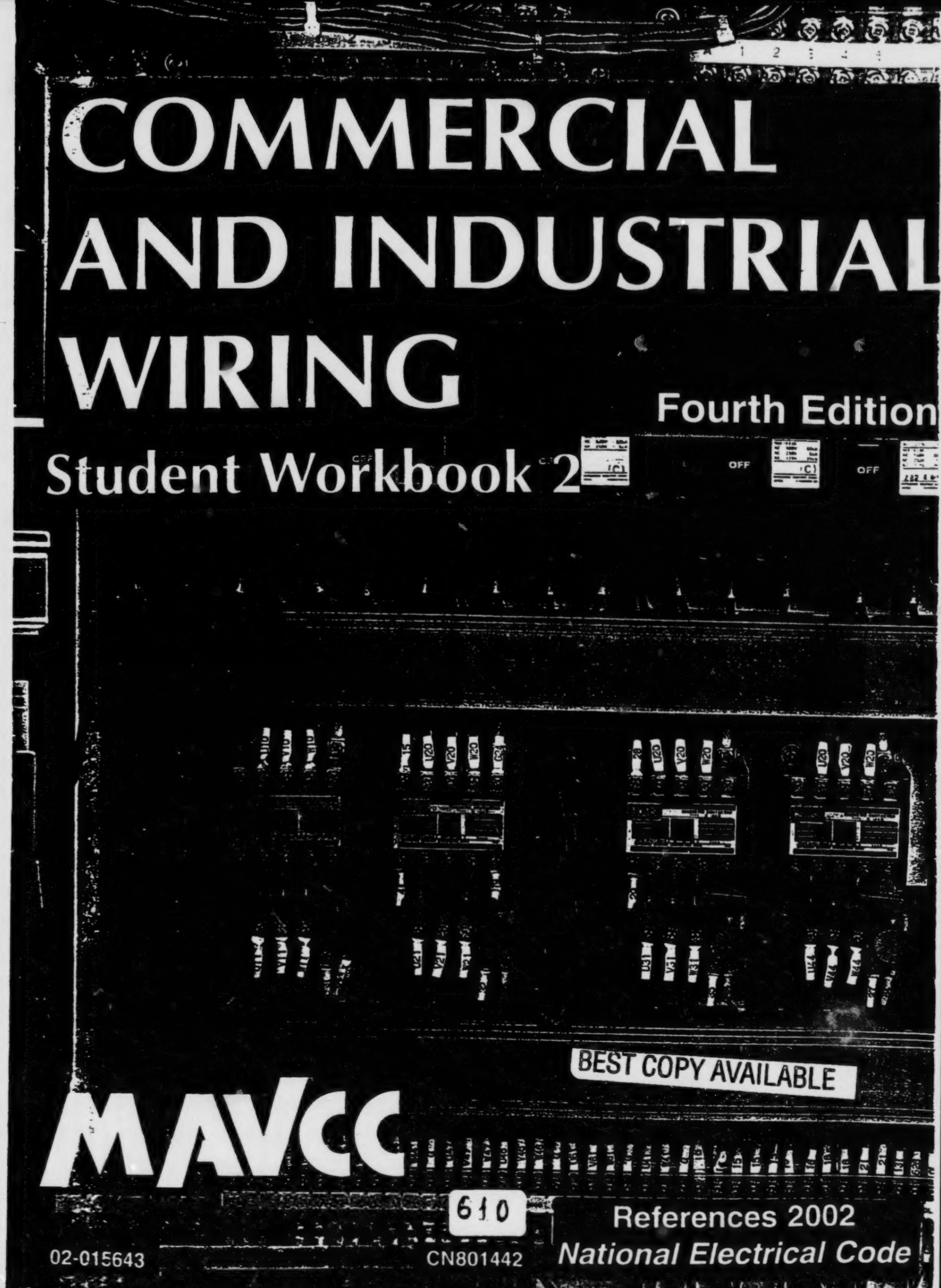
e. ______________________________

f. ______________________________

g. ______________________________

h. ______________________________

i. ______________________________



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National Electrical Code

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Student Workbook 2

Units 9–16

Written by

Stan Kaltwasser
Gary Flowers

Revised by

Dan Ipock

Project coordinated by

Glenn Fleming

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Multistate Academic and Vocational Curriculum Consortium, Inc.
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For more information, contact the
Multistate Academic and Vocational Curriculum Consortium
1500 West Seventh Avenue
Stillwater, OK 74074-4364

E-mail: mavcc@mavcc.com
Internet: http://www.mavcc.org
Phone: (800)654-3988 or (405)743-5578

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Objective 8

Assignment Sheet 1—Complete a Ladder and a Wiring Diagram of a Two-Wire Control Using a Thermal Switch

Name ____________________ Overall Rating __________

Date ____________________

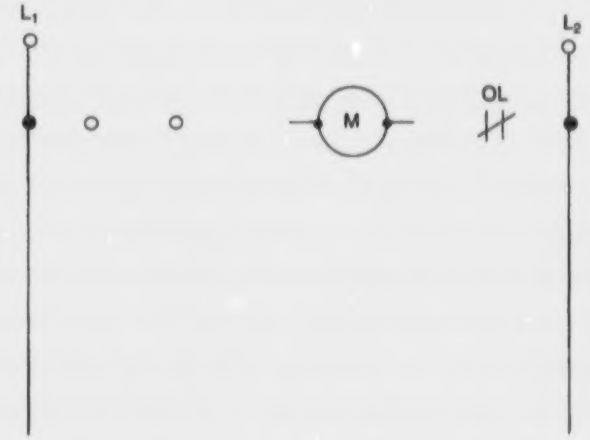
Evaluation Criteria	Rating
• Legibly drawn	______
• Correct symbols used	______
• Accurate depiction in ladder diagram	______
• Accurate depiction in wiring diagram	______

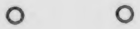
Basic Skills

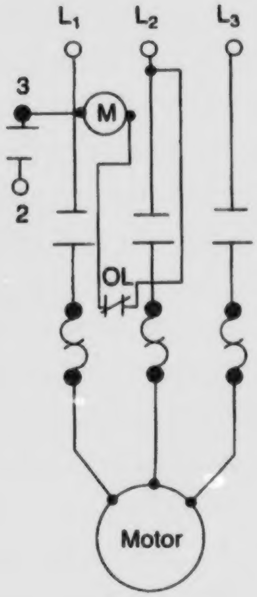
Reading Writing

Directions

Complete the ladder and wiring diagrams below, using a thermal switch. The above criteria will be used to evaluate your performance.






L_1
L_2
L_3
3
M
2
OL
Motor

Objective 9

Assignment Sheet 2—Draw a Ladder Diagram of a Three-Wire Control With an "On" Indicating Pilot Light

Name ______________________________ Overall Rating __________

Date ______________________________

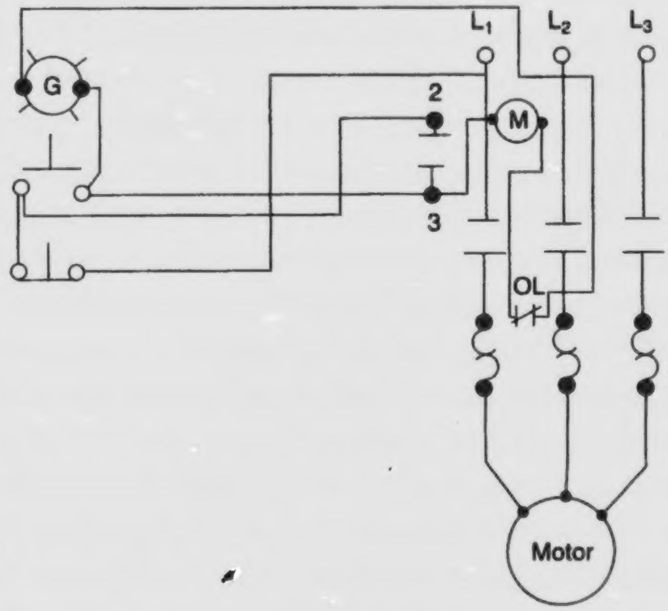
Evaluation Criteria	**Rating**
• Legibly drawn	______
• Correct symbols used	______
• Accurate conversion to ladder diagram	______

Basic Skills

Reading Writing

Directions

Convert the following wiring diagram to a ladder diagram. The above criteria will be used to evaluate your performance.



Objective 10

Assignment Sheet 3—Draw a Ladder and a Wiring Diagram of a Three-Wire Control With an "Off" Indicating Pilot Light

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Legibly drawn	______
• Correct symbols used	______
• Accurate depiction in wiring diagram	______
• Accurate depiction in ladder diagram	______

Basic Skills

Reading Writing

Directions

Draw a ladder and a wiring diagram of a three-wire control with an "off" indicating pilot light in the space provided below. The above criteria will be used to evaluate your performance.

Note: In order to operate the pilot light correctly, an additional set of normally closed auxiliary contacts must be added.

Objective 11

Assignment Sheet 4—Determine the Number and Size of Conductors Needed to Operate a Two-Wire Control System

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	**Rating**
• Ability to use *NEC*	______
• Ability to "read" drawing	______
• Correct answers given	______

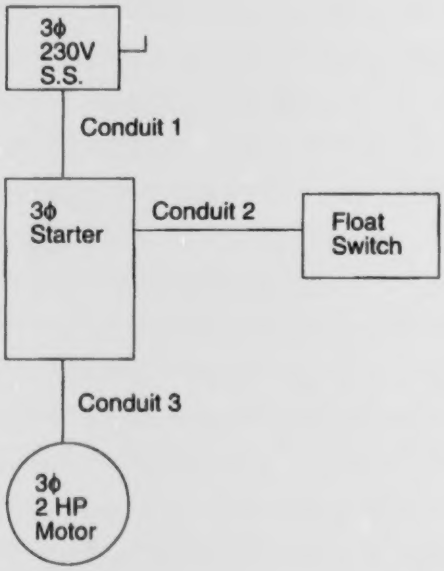
Basic Skills

Reading Mathematics

Directions

Using the drawing below and the *NEC*, determine the number of power and control conductors needed to operate the system. You must also determine the proper size conduit and the proper fuse size (dual element, time delay). The above criteria will be used to evaluate your performance.

Note: It may simplify the conductor count to draw a wiring diagram of this system.



a. Conduit 1 _______ inch EMT; _______ conductors; _______ AWG THWN

b. Conduit 2 _______ inch EMT; _______ conductors; _______ AWG THWN

c. Conduit 3 _______ inch EMT; _______ conductors; _______ AWG THWN

d. Dual element time delay fuse size = _______ amperes

Objective 12

Assignment Sheet 5—Determine the Number and Size of Conductors Needed to Operate a Three-Wire Control System

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Ability to use *NEC*	______
• Ability to "read" drawing	______
• Correct answers given	______

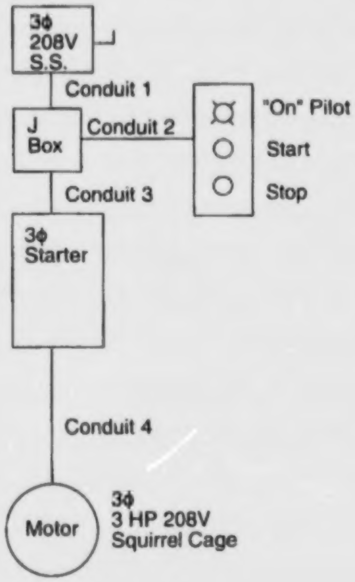
Basic Skills

Reading Mathematics

Directions

Using the drawing below and the *NEC*, determine the number of power and control conductors needed to operate the system. You must also determine the proper size conduit and the proper fuse size (dual element, time delay). The above criteria will be used to evaluate your performance.

Note: This starter has a line voltage coil.


3ϕ
208V
S.S.
Conduit 1
J
Box
Conduit 2
"On" Pilot
Start
Stop
Conduit 3
3ϕ
Starter
Conduit 4
Motor
3ϕ
3 HP 208V
Squirrel Cage

a. Conduit 1 _______ inch EMT; _______ conductors; _______ AWG TW

b. Conduit 2 _______ inch EMT; _______ conductors; _______ AWG THWN

c. Conduit 3 _______ inch EMT; _______ conductors; _______ AWG TW

d. Conduit 4 _______ inch EMT; _______ conductors; _______ AWG TW

e. Dual element time delay fuse size = _______ amperes

Objective 13

Job Sheet 1—Wire a Two-Wire Control

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	____
• Ladder diagram correct	____
• Wiring diagram correct	____
• Sequence of operation correct	____
• Equipment mounted properly	____
• System operates	____
• Demonstrated good workmanship	____
• Complied to *NEC*	____

Basic Skills

Reading Writing Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools
- Three-phase open starter
- Five feet #14 THHN
- Mounting board
- Four #10 x 1" sheet metal screws
- Float switch (momentary N/O push button, to simulate action of float switch)

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder diagram and a wiring diagram of your system in the space provided below.

☐ 4. Have your instructor approve your drawing.

☐ 5. In complete sentences, describe the sequence of operation of the system.

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☐ 6. Mount the equipment.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate the job.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 14

Job Sheet 2—Wire Two Float Switches to Operate a Starter (Series Connection)

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Ladder diagram correct	______
• Wiring diagram correct	______
• Sequence of operation correct	______
• Equipment mounted properly	______
• System operates	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Writing Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools
- Three-phase open starter
- Five feet #14 THHN
- Mounting board
- Four #10 x 1" sheet metal screws
- Two float switches (momentary N/O push button, to simulate action of float switch)

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder diagram and a wiring diagram of your system in the space provided below.

☐ 4. Have your instructor approve your drawing.

☐ 5. In complete sentences, describe the sequence of operation of the system.

☐ 6. Mount the equipment.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate the job.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 15

Job Sheet 3—Wire Two Float Switches to Operate a Starter (Parallel Connections)

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Ladder diagram correct	______
• Wiring diagram correct	______
• Sequence of operation correct	______
• Equipment mounted properly	______
• System operates	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Writing Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools
- Three-phase open starter
- Five feet #14 THHN
- Mounting board
- Four #10 x 1" sheet metal screws
- Two float switches (momentary N/O push button, to simulate action of float switch)

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder diagram and a wiring diagram of your system in the space provided below.

☐ 4. Have your instructor approve your drawing.

☐ 5. In complete sentences, describe the sequence of operation of the system.

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☐ 6. Mount the equipment.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate the job.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ____________________

____

____

Objective 16

Job Sheet 4—Wire a Pressure Switch to Operate a Starter with "On" and "Off" Pilot Lights

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Ladder diagram correct	______
• Wiring diagram correct	______
• Sequence of operation correct	______
• Equipment mounted properly	______
• System operates	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Writing Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools
- Three-phase open starter (with additional N/C auxiliary contacts)
- Six feet #14 THHN
- Ten #10 x 1" sheet metal screws
- Pressure switch (momentary N/O push button, to simulate action of pressure switch
- Two 120 volt pilot lights

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder diagram and a wiring diagram of your system in the space provided below.

☐ 4. Have your instructor approve your drawing.

☐ 5. In complete sentences, describe the sequence of operation of the system.

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☐ 6. Mount the equipment.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate the job.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 17

Job Sheet 5—Wire a Three-Wire Control System

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
• Practiced safety rules throughout procedure	______
• Ladder diagram correct	______
• Wiring diagram correct	______
• Sequence of operation correct	______
• Equipment mounted properly	______
• System operates	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Writing Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools
- Three-phase open starter
- Six feet #14 THHN
- Mounting board
- Six #10 x 1" sheet metal screws
- Start/stop station (1-N/O push button, 1-N/C push button)

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder diagram and a wiring diagram of your system in the space provided below.

☐ 4. Have your instructor approve your drawing.

☐ 5. In complete sentences, describe the sequence of operation of the system.

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☐ 6. Mount the equipment.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate the job.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 18

Job Sheet 6—Wire a Multiple Station Three-Wire Control

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Ladder diagram correct	______
• Wiring diagram correct	______
• Sequence of operation correct	______
• Equipment mounted properly	______
• System operates	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Writing Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools
- Three-phase open starter
- Two start/stop stations
- Eight #10 x 1" sheet metal screws
- Mounting board
- Ten feet #14 THHN

Procedure

Note: Stops are wired in series and starts are wired in parallel with the auxiliary contacts.

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder diagram and a wiring diagram of your system in the space provided below.

☐ 4. Have your instructor approve your drawing.

☐ 5. In complete sentences, describe the sequence of operation of the system.

☐ 6. Mount the equipment.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate the job.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 19

Job Sheet 7—Wire a Multiple Station Three-Wire Control with "On" and "Off" Pilot Lights

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Ladder diagram correct	______
• Wiring diagram correct	______
• Sequence of operation correct	______
• Equipment mounted properly	______
• System operates	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Writing Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools
- Three-phase open starter (extra N/C contacts)
- Two start/stop stations
- Two 120 volt pilot lights
- Ten feet #14 THHN
- Twelve #10 x 1" sheet metal screws

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder diagram and a wiring diagram of your system in the space provided below.

☐ 4. Have your instructor approve your drawing.

☐ 5. In complete sentences, describe the sequence of operation of the system.

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☐ 6. Mount the equipment.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate the job.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ____________________

____

____

Objective 7

Assignment Sheet 1—Read and Interpret Ladder Diagrams Using Separate Control Circuits

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Correct sequence of operation given	______
• Answers legibly written	______

Basic Skills

Reading

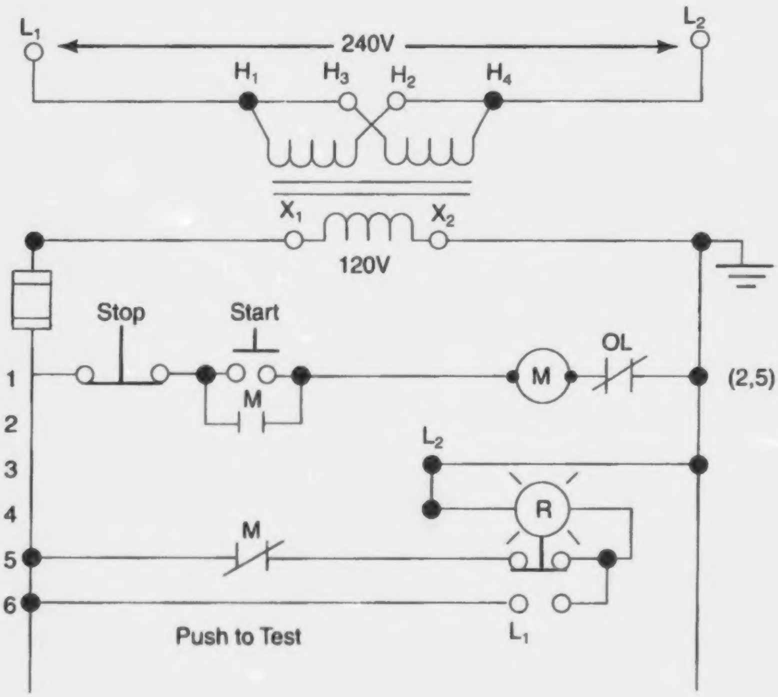
Writing

Critical Thinking

Directions

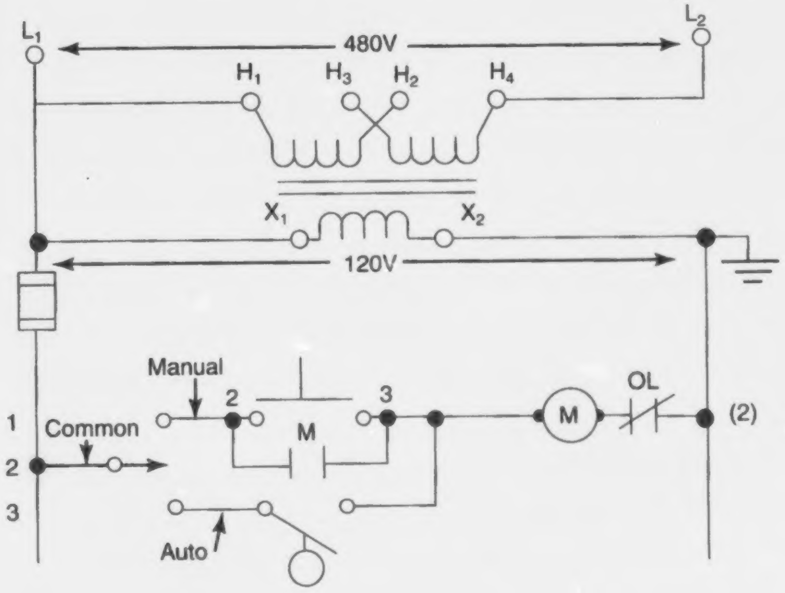
Read the following ladder diagrams and describe the sequence of operation in the space provided. The above criteria will be used to evaluate your performance.

a.

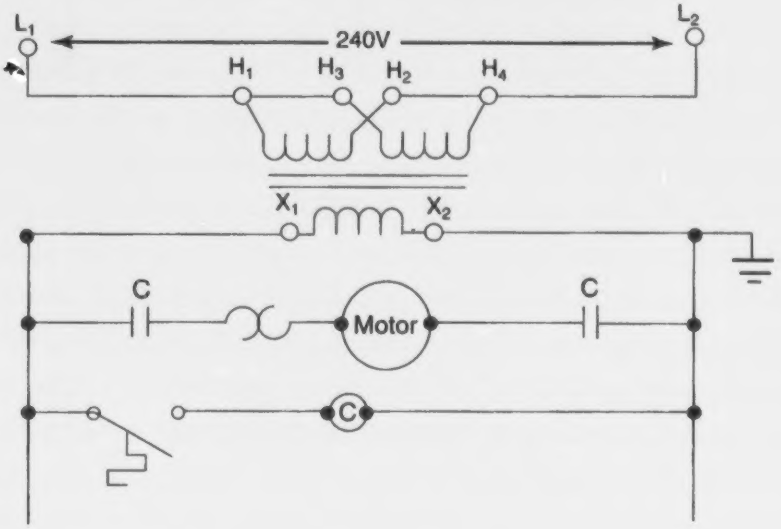


L_1
240V
L_2
H_1
H_3
H_2
H_4
X_1
X_2
120V
Stop
Start
M
OL
(2,5)
1
2
3
4
5
6
L_2
R
M
Push to Test
L_1

b.


L1
L2
480V
H1
H3
H2
H4
X1
X2
120V
Manual
2
3
1
Common
M
2
3
Auto
M
OL
(2)

c.


L1
L2
240V
H1
H3
H2
H4
X1
X2
C
C
Motor
C

Objective 8

Assignment Sheet 2—Answer Questions About Control Circuits

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Correct use of the *NEC* demonstrated	______
• Correct answers given	______

Basic Skills

Reading

Directions

Using the *NEC*, answer the following questions that deal with control circuits. Specify the appropriate article number in the space provided. The above criteria will be used to evaluate your performance.

a. If the #16 AWG control circuit conductors extend beyond the control equipment enclosure and are tapped from the motor branch circuit, is supplementary fuse protection required if the motor branch circuit is fused at 60 amperes?

____

Article ______________________________

b. May a control transformer located within a motor controller enclosure be tapped from the line side of the disconnecting means?

____

Article ______________________________

c. May the motor control circuit disconnecting means be located in a separate room from the motor circuit disconnecting means?

____

Article ______________________________

d. What is the maximum percentage of rated primary current that an overcurrent device may be rated or set if the control circuit transformer rated primary current is less than 2 amperes?

____

Article ______________________________

Objective 9

Assignment Sheet 3—Determine the Size and Number of Conductors Needed to Operate a Separate Control Circuit

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Correct use of the *NEC* demonstrated	______
• Correct answers given	______

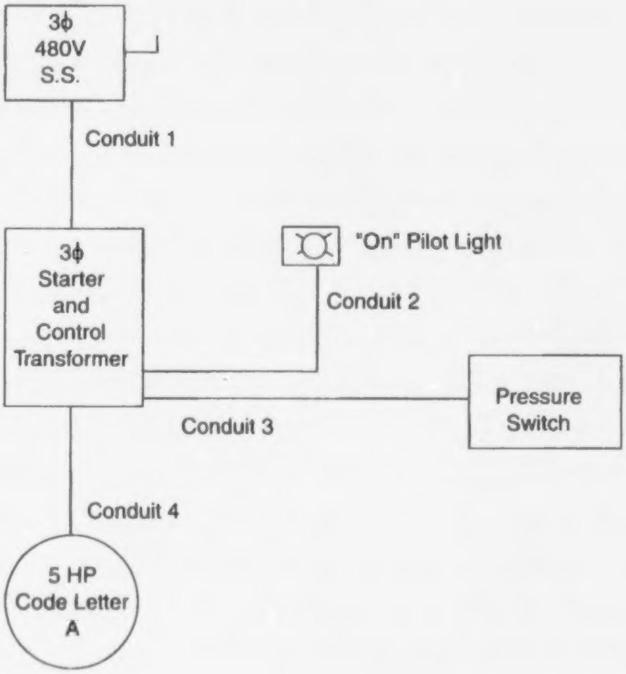
Basic Skills

Reading Mathematics

Directions

Using the *NEC* and additional materials supplied to you by your instructor, answer the questions following the diagram shown below. The above criteria will be used to evaluate your performance.

Note: Coil voltage is 120 volts.


3ϕ
480V
S.S.
Conduit 1
3ϕ
Starter
and
Control
Transformer
"On" Pilot Light
Conduit 2
Conduit 3
Pressure
Switch
Conduit 4
5 HP
Code Letter
A

a. Conduit 1 ________________ conductors; ______________ AWG

b. Conduit 2 ________________ conductors; ______________ AWG

c. Conduit 3 ________________ conductors; ______________ AWG

d. Conduit 4 ________________ conductors; ______________ AWG

e. Fuse size ________________ (Dual element time delay)

Objective 10

Job Sheet 1—Wire a Relay and a Load with a Separate Control Circuit

Name ______________________ Attempt Number ______

Date ______________________ Overall Rating ______

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Ladder diagram correct	______
• Wiring diagram correct	______
• System operates	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Writing Employability Critical Thinking

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools
- Four pole relay with 24 volt coil (4 N/O)
- 120/24 volt transformer
- Start/stop station
- Mounting board
- Eight #10 x 1″ sheet metal screws
- Ten feet #16 TFF
- Pilot light

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder and a wiring diagram of a control system using one start/stop station to control a 4-pole relay. The relay will operate a 120 volt pilot light and will be actuated by 24 volts.

☐ 4. Have your instructor approve your drawings.

☐ 5. In complete sentences, describe the sequence of operation of your control system.

☐ 6. Have your instructor approve your description.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate your work.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 11

Job Sheet 2—Wire a Three-Phase Starter to Operate by a Separate Control Circuit

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation Criteria	**Rating**
• Practiced safety rules throughout procedure	______
• Gave proper sequence description	______
• System operates	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Writing Employability Critical Thinking

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

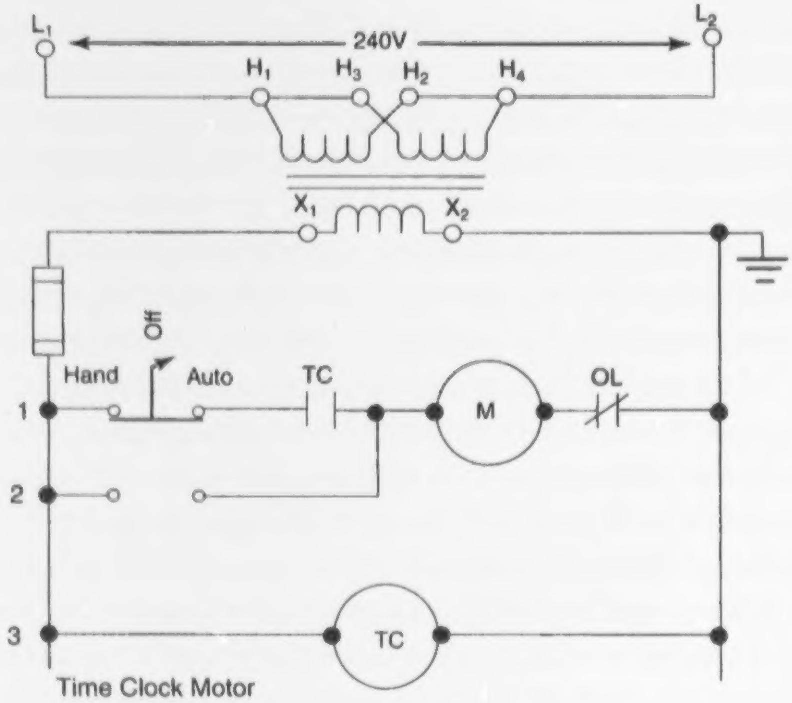
- Pouch tools
- 3ϕ starter with 120 volt coil
- 240 volt (live) 3ϕ power source
- 480-240/120 control transformer
- Fuse block
- 6/10 amp fuse
- Mounting board
- Three-position selector switch and enclosure
- Twelve #10 x 1″ sheet metal screws
- 15 feet #14 THHN
- 24 hour time clock with 120 volt timer motor

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Using the following ladder diagram, write a complete sequence of operation of the system.



L_1
240V
L_2
H_1
H_3
H_2
H_4
X_1
X_2
Off
Hand
Auto
TC
M
OL
1
2
3
TC
Time Clock Motor

- ☐ 4. Have your instructor approve your sequence description.
- ☐ 5. Wire the system.
- ☐ 6. Have your instructor evaluate your work.
- ☐ 7. Disassemble the system.
- ☐ 8. Return tools and materials to proper storage.
- ☐ 9. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 8

Assignment Sheet 1—Answer Questions Related to a Sequence Control Diagram

Name ______________________ Overall Rating __________

Date ______________________

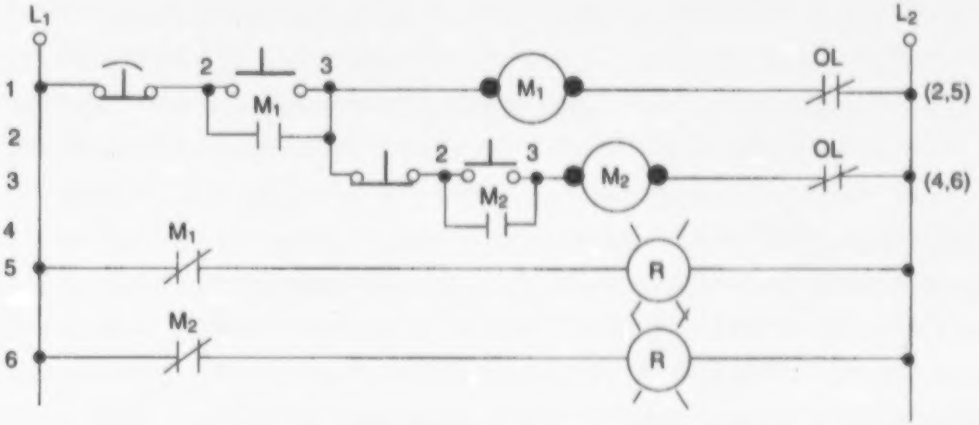
Evaluation Criteria	**Rating**
• Correct answers given	______
• Answers written legibly	______
• Correct explanation of answers given	______

Basic Skills

Reading Writing

Directions

Answer the following questions related to the sequence control diagram shown below. The above criteria will be used to evaluate your performance.



a. When the start button on Rung 1 is pressed, what is the sequence of events?

____

____

____

____

b. When the start button on Rung 3 is pressed, what is the sequence of events when M_1 is not energized?

____

____

____

____

c. If both coils M_1 and M_2 are energized, what is the sequence of events if the stop button on Rung 3 is pressed?

____

____

____

____

d. If both coils M_1 and M_2 are energized, what is the sequence of events if the stop button on Rung 1 is pressed?

____

____

____

____

e. Is it possible to energize coil M_2 if coil M_1 is not energized? Explain your answer.

____

____

____

____

Objective 9

Assignment Sheet 2—Answer Questions Related to an Auxiliary Contact Interlocking Diagram

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Correct answers given	______
• Answers written legibly	______
• Correct explanation of answers given	______

Basic Skills

Reading Writing

Directions

Answer the following questions related to the auxiliary contact interlocking diagram shown on the following page. The above criteria will be used to evaluate your performance.

a. List in order the sequence of events when the start button on Rung 10 is pressed.

____

____

____

____

b. If no coils are energized, what pilot lights are "on" and what is their purpose?

____

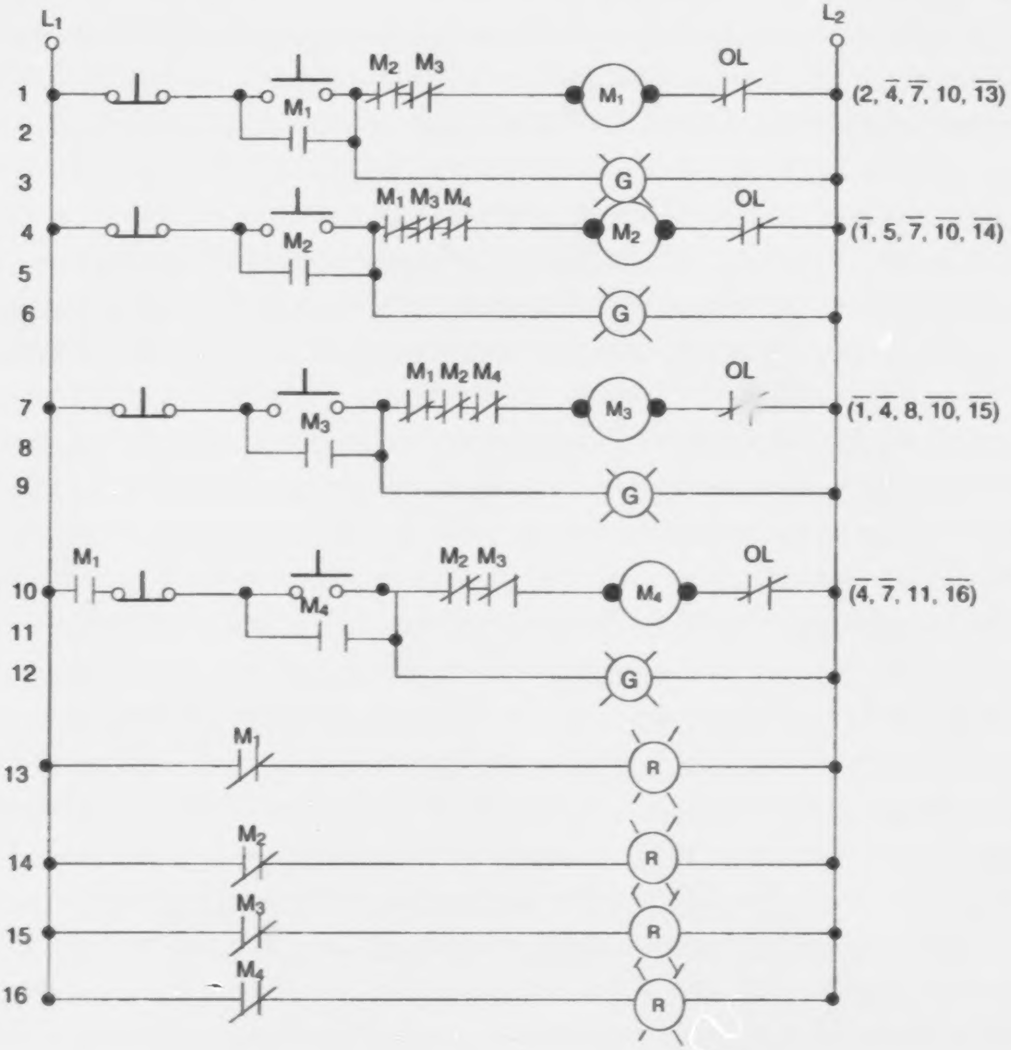
____

____

____

Assignment Sheet 2

c. Is it possible to energize coil M_4 and coil M_1 at the same time? Explain your answer.


L1
L2
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
M1
M2 M3
M1
OL
G
(2, $\overline{4}$, $\overline{7}$, 10, $\overline{13}$)
M2
M1 M3 M4
M2
OL
G
($\overline{1}$, 5, $\overline{7}$, $\overline{10}$, $\overline{14}$)
M3
M1 M2 M4
M3
OL
G
($\overline{1}$, $\overline{4}$, 8, $\overline{10}$, $\overline{15}$)
M1
M4
M2 M3
M4
OL
G
($\overline{4}$, $\overline{7}$, 11, $\overline{16}$)
M1
R
M2
R
M3
R
M4
R

Objective 10

Job Sheet 1—Wire Two Starters in Sequence

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Ladder diagram correct	______
• Explanation correct	______
• System operates	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Writing Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Two three-phase starters
- Two start/stop stations
- Twelve #10 x 1" sheet metal screws
- 15 feet #16 TFFN
- Mounting board

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder diagram of a system to operate two starters in sequence. Starter 1 must be energized before starter 2 is able to run.

☐ 4. Have your instructor approve your diagram.

☐ 5. In complete sentences, explain how your system operates.

☐ 6. Have your instructor approve your explanation.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate the job.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 11

Job Sheet 2—Wire Two Starters with Auxiliary Contact Interlocking

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Ladder diagram correct	______
• Explanation correct	______
• System operates	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Writing Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Two three-phase starters (with N/C auxiliary contacts)
- Two start/stop stations
- Twelve #10 x 1" sheet metal screws
- 15 feet #16 TFFN
- Mounting board
- Two pilot lights

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder diagram of a system designed to prevent two starters from being energized simultaneously. The starters must also indicate their energized status throughout the use of pilot lights.

☐ 4. Have your instructor approve your drawing

☐ 5. In complete sentences, explain how your system operates.

☐ 6. Have your instructor approve your explanation.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate the job.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 5

Assignment Sheet 1—Convert Ladder Diagrams to Wiring Diagrams

Name ______________________ Overall Rating ________

Date ______________________

Evaluation Criteria	Rating
• Completeness of diagrams	______
• Systems will work as drawn	______
• Labels and connections legible	______

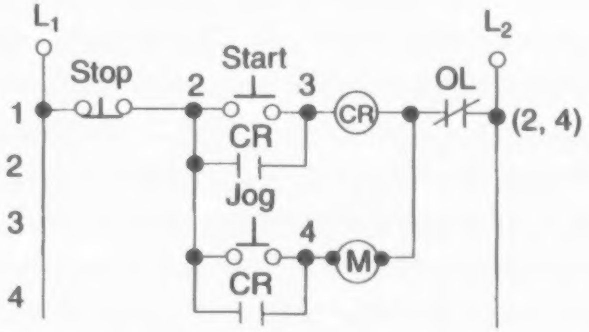
Basic Skills

Reading Writing

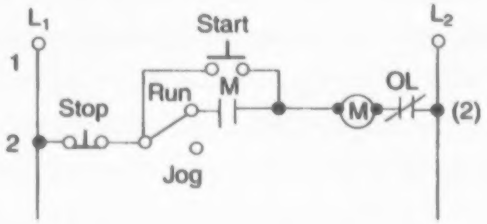
Directions

Convert the ladder diagrams shown below to wiring diagrams. The above criteria will be used to evaluate your performance.

a.



b.


L1
Start
L2
1
M
OL
Run
Stop
(2)
2
Jog

Objective 6

Assignment Sheet 2—Determine the Number of Conductors Needed to Operate Jogging Controls

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Correct answers given	______
• Demonstrated ability to use *NEC* and other resource materials	______

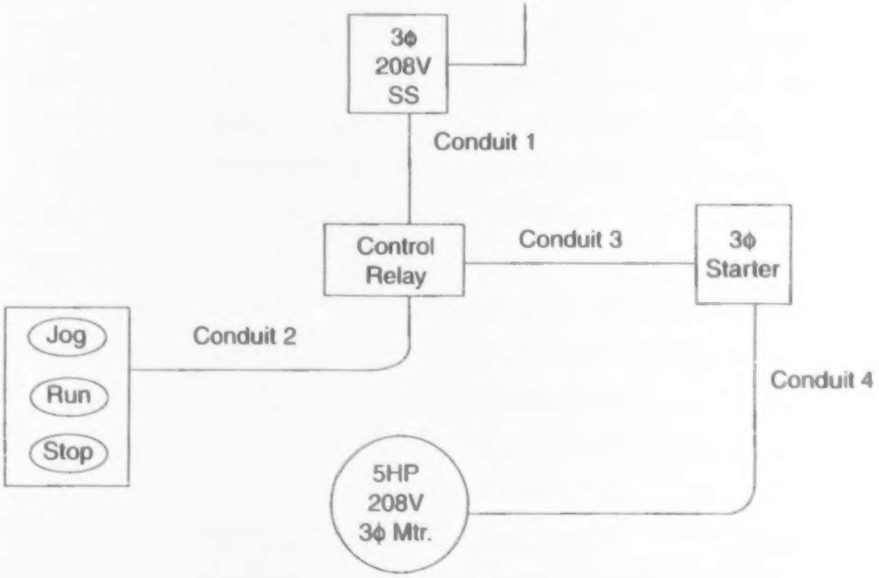
Basic Skills

Reading Mathematics

Directions

Using the *NEC* and other materials provided by instructor, determine the size and number of conductors needed to operate the following jogging control circuits. You must also determine the proper fuse size using a dual element time delay fuse, and the proper heater size. The above criteria will be used to evaluate your performance.

Note: This starter has a line voltage coil.


3ϕ
208V
SS
Conduit 1
Control Relay
Conduit 3
3ϕ Starter
Jog
Run
Stop
Conduit 2
Conduit 4
5HP
208V
3ϕ Mtr.

Conduit 1—______________ conductors; ______________ AWG

Conduit 2—______________ conductors; ______________ AWG

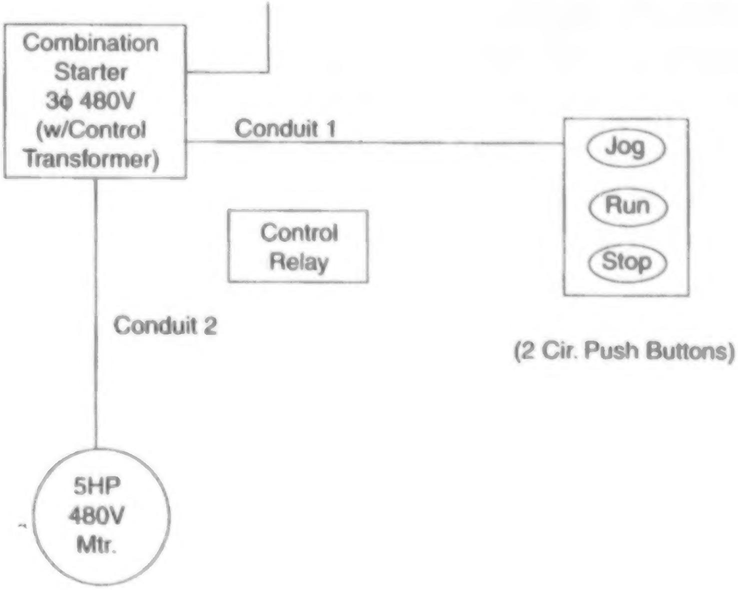
Conduit 3—______________ conductors; ______________ AWG

Conduit 4—______________ conductors; ______________ AWG

Dual element fuse—______________ amps

Heater—______________

b.


Combination Starter 3ϕ 480V (w/Control Transformer)
Conduit 1
Jog
Run
Stop
Control Relay
Conduit 2
(2 Cir. Push Buttons)
5HP 480V Mtr.

Conduit 1—______________ conductors; ______________ AWG

Conduit 2—______________ conductors; ______________ AWG

Fuse size—______________ (dual element time delay)

Heater amps—______________; part number ______________

Objective 7

Job Sheet 1—Wire a Jog Through a Lock-Stop Push Button

Name ______________________ Attempt Number ______

Date ______________________ Overall Rating ______

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Ladder diagram correct	______
• Sequence description correct	______
• Proper operation	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Writing Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools
- Three-phase starter
- Three-element control station
- Normally open push button
- Two normally closed push buttons
- Lock-stop device
- Eight #10x1" sheet metal screws
- 15 feet of #14 THHN

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder diagram of a jogging control using a lock-stop push button.

☐ 4. Have your instructor approve your diagram.

☐ 5. In complete sentences, describe the sequence of operation of your system.

☐ 6. Have your instructor approve your explanation.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate the job.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ______________________________

Objective 8

Job Sheet 2—Wire a Jog Through a Two-Position Selector

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Ladder diagram correct	______
• Sequence description correct	______
• Proper operation	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Writing Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools
- Three-phase starter
- Three-element control station
- N/O push button
- N/C push button
- N/O two-position selector switch
- Eight #10x1" sheet metal screws
- 15 feet of #14 THHN

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder diagram of a jogging control using a two-position selector switch.

☐ 4. Have your instructor approve your diagram.

☐ 5. In complete sentences, describe the sequence of operation of your system.

☐ 6. Have your instructor approve your explanation.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate the job.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 9

Job Sheet 3—Wire a Jog Through a Two-Circuit Push Button

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
• Practiced safety rules throughout procedure	______
• Ladder diagram correct	______
• Sequence description correct	______
• Proper operation	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Writing Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools
- Three-phase starter
- Three-element control station
- N/O push button
- N/C push button
- N/O-N/C two-circuit push button
- Eight #10x1″ sheet metal screws
- 15 feet of #14 THHN

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder diagram of a jogging control using a two-circuit push button.

☐ 4. Have your instructor approve your diagram.

☐ 5. In complete sentences, describe the sequence of operation of your system.

☐ 6. Have your instructor approve your explanation.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate the job.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 10

Job Sheet 4—Wire a Jog Through a Control Relay

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Ladder diagram correct	______
• Sequence description correct	______
• Proper operation	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Writing Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools
- Three-phase starter
- Three-element control station
- Two N/O push buttons
- N/C push button
- Two pole control relay with compatible coil voltage
- Eight #10x1" sheet metal screws
- 15 feet of #14 THHN

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder diagram of a jogging control using a control relay.

☐ 4. Have your instructor approve your diagram.

☐ 5. In complete sentences, describe the sequence of operation of your system.

☐ 6. Have your instructor approve your explanation.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate the job.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ____

____

____

Objective 6

Assignment Sheet 1—Describe the Sequence of Operation of Ladder Diagrams

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Correct sequence given for Diagram A	______
• Correct sequence given for Diagram B	______
• Correct sequence given for Diagram C	______
• Legible writing	______

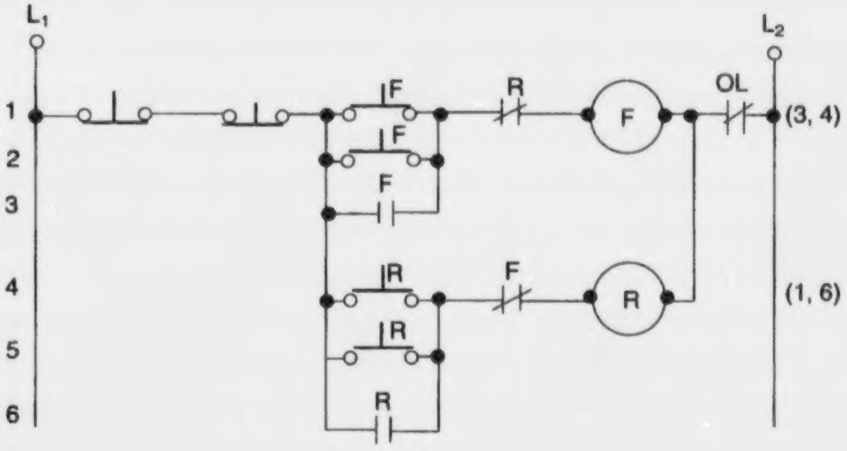
Basic Skills

Reading Writing

Directions

Describe the sequence of operation of the three ladder diagrams shown below. The above criteria will be used to evaluate your performance.

a.



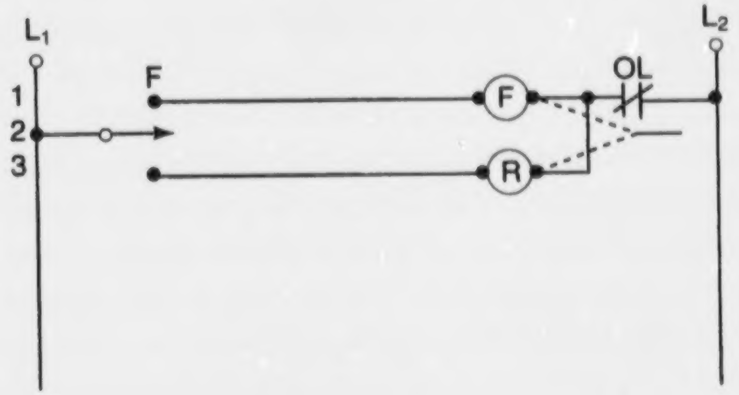
____

____

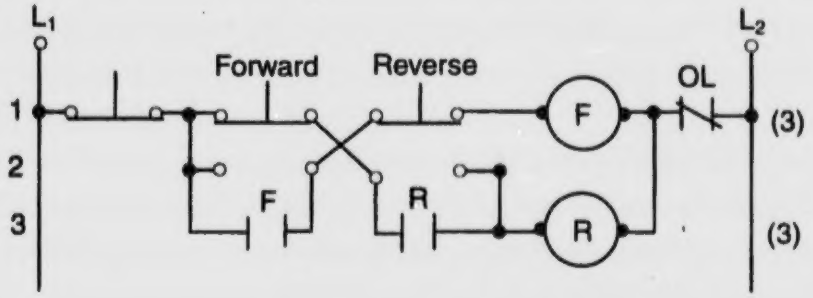
____

____

b.


L1
L2
1
2
3
F
OL
F
R

c.


L1
L2
Forward
Reverse
OL
1
2
3
F
R
F
R
(3)
(3)

Objective 7

Assignment Sheet 2—Determine the Number of Conductors Needed to Operate a Reversing Control

Name ______________________ Overall Rating __________

Date ______________________

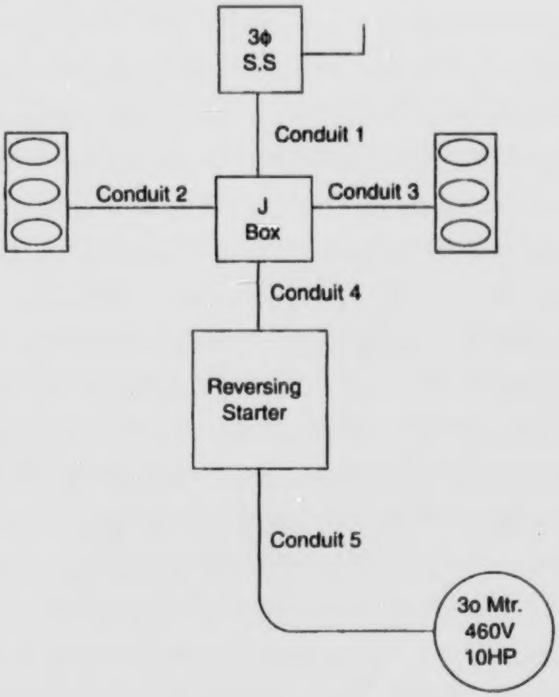
Evaluation Criteria	**Rating**
• Correct answers given	______
• Complied to *NEC*	______

Basic Skills

Reading Mathematics

Directions

Determine the number of 14 Awg control conductors needed to operate the control circuit of a system using two control stations with push button and auxiliary contact interlock. Also determine the number and size of motor branch circuit conductors as well as the size of conduit. The above criteria will be used to evaluate your performance.


3ϕ
S.S
Conduit 1
Conduit 2
J
Box
Conduit 3
Conduit 4
Reversing
Starter
Conduit 5
3o Mtr.
460V
10HP

Assignment Sheet 2

Conduit 1—__________ inch; __________ conductors; ________ AWG THW

Conduit 2—__________ inch; __________ conductors; ________ AWG THW

Conduit 3—__________ inch; __________ conductors; ________ AWG THW

Conduit 4—__________ inch; __________ conductors; ________ AWG THW

Conduit 5—__________ inch; __________ conductors; ________ AWG THW

Objective 8

Job Sheet 1—Wire a Reversing Starter with a Three-Position Selector Switch

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Diagram correct	______
• Explanation correct	______
• System operates	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Writing Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools
- Three-position selector switch (N/O-N/O) and enclosure
- Reversing starter with mechanical interlock
- Eight #10 x 1″ sheet metal screws
- 15 feet of #16 THWN
- Mounting board

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder diagram of a control system using a three-position selector switch to operate a reversing starter.

☐ 4. Have your instructor approve your diagram.

☐ 5. In complete sentences, explain how your system operates.

☐ 6. Have your instructor approve your explanation.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate the job.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 9

Job Sheet 2—Wire a Reversing Starter with One Control Station Using Auxiliary Contact and Mechanical Interlock

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Diagram correct	______
• Explanation correct	______
• System operates	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Writing Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools
- Three-element control station
- N/C push button
- Two N/O push buttons
- Reversing starter with mechanical interlock
- Eight #10 x 1″ sheet metal screws
- 15 feet of #16 THWN
- Mounting board

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder diagram of a reversing control with one control station, using auxiliary contact and mechanical interlocking.

☐ 4. Have your instructor approve your diagram.

☐ 5. In complete sentences, explain how your system operates.

☐ 6. Have your instructor approve your explanation.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate the job.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ____________________

Objective 10

Job Sheet 3—Wire a Reversing Starter with One Control Station Using Push-Button and Auxiliary Contact Interlocking

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Diagram correct	______
• Explanation correct	______
• System operates	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Writing Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools
- Three-element control station
- N/C push button
- Two N/O-N/C two circuit push buttons
- Reversing starter
- Eight #10 x 1" sheet metal screws
- 15 feet of #16 THWN
- Mounting board

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder diagram of a system to operate a reversing starter using push button and auxiliary contact interlocking.

☐ 4. Have your instructor approve your diagram.

☐ 5. In complete sentences, explain how your system operates.

☐ 6. Have your instructor approve your explanation.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate the job.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ______________________________

Objective 11

Job Sheet 4—Wire a Reversing Starter with Two Control Stations

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Diagram correct	______
• Explanation correct	______
• System operates	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Writing Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools
- Two forward/reverse/stop control stations
- Reversing starter
- Ten #10 x 1" sheet metal screws
- 20 feet of #16 THWN
- Mounting board

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a ladder diagram of a reversing control using two control stations.

☐ 4. Have your instructor approve your diagram.

☐ 5. In complete sentences, explain how your system operates.

____

____

____

____

____

____

____

____

____

☐ 6. Have your instructor approve your explanation.

☐ 7. Wire the system.

☐ 8. Have your instructor evaluate the job.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ____________________

____

____

Objective 12

Job Sheet 5—Wire Drum Switches

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Diagram correct	______
• Switches reversed motor rotation	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Writing Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Part I

Tools, Equipment, and Materials

- Pouch tools
- Drum switch for polyphase motors
- 3ϕ 3/4hp. motor
- 3ϕ voltage source
- Two #10 x 1″ sheet metal screws
- Mounting board

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a wiring diagram of a drum switch.

Note: Terminal connections for polyphase motors are located on the inside of the drum switch cover.

☐ 4. Have your instructor approve your diagram.

☐ 5. Wire the drum switch

☐ 6. Have your instructor evaluate the job.

☐ 7. Disassemble the system.

☐ 8. Return tools and materials to proper storage.

☐ 9. Clean the work area.

Evaluator's Comments: ____

____

____

Part II

Tools, Equipment, and Materials

- Pouch tools
- Drum switch for 1ϕ motor
- 1ϕ 3/4hp. motor
- 1ϕ 240V voltage source
- Two #10 x 1″ sheet metal screws
- Mounting board

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Draw a wiring diagram of a drum switch.

Note: Terminal connections for single-phase motors are located on the inside of the drum switch cover.

☐ 4. Have your instructor approve your diagram.

☐ 5. Wire the drum switch

☐ 6. Have your instructor evaluate the job.

☐ 7. Disassemble the system.

☐ 8. Return tools and materials to proper storage.

☐ 9. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 13

Job Sheet 6—Wire a Reversing Starter with Jog in Both Directions

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
• Practiced safety rules throughout procedure	______
• Starter operated correctly	______
• Jog operated correctly	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading

Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools
- N/C push button
- Two N/O push buttons
- Two N/O-N/C two-circuit push buttons
- Three element control station
- Two element control station
- Reversing starter
- Mounting board
- Ten #10 x 1″ sheet metal screws
- 20 feet of #16 THWN

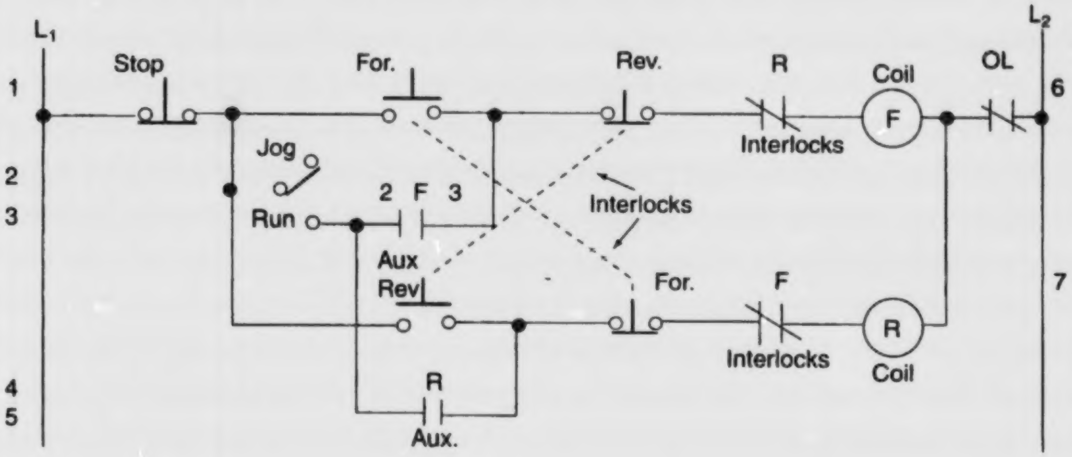
Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

Job Sheet 6

☐ 3. Wire a reversing starter with jog in both directions, using the following diagram.


L1
L2
Stop
For.
Rev.
R
Coil
OL
1
6
F
Interlocks
Jog
2
3
Run
2 F 3
Interlocks
Aux
Rev
For.
F
7
R
Interlocks
Coil
4
5
R
Aux.

☐ 4. Have your instructor evaluate your job.

☐ 5. Disassemble the system.

☐ 6. Return tools and materials to proper storage.

☐ 7. Clean the work area.

Evaluator's Comments: ______________________

____

____

Objective 10

Job Sheet 1—Build a Relay Control Circuit

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Ladder diagram correct	______
• Explanation correct	______
• System operates	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Writing Employability Critical Thinking

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools
- Four 120 volt pilot lights
- Four 4-pole relays with 120 volt coils (N/O)
- N/C push button
- Four N/O push buttons
- 20 feet of #16 THWN

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Design a control system to solve the following scenario problem:

A contest for industrial electricity students has been organized to test the students over *National Electrical Code* knowledge. Four students will participate. Each will be seated at a desk containing a push button station. A question will be asked by the facilitator. The first contestant with the answer will press the push button that will energize a pilot light in front of the desk. It will also lock out the other three contestants' lights. The facilitator, upon receiving a correct response to the question, may then reset the system by pressing another push button. You have been asked to design and build the control system. Draw a diagram of your design in the space provided below.

☐ 4. Draw a ladder diagram of your control system in the space provided below. (Be sure to reference your diagram.)

☐ 5. In complete sentences, explain in detail how your system operates.

____

____

____

____

____

____

____

____

☐ 6. Have your instructor approve your diagram and explanation.

☐ 7. Build a prototype of the system.

☐ 8. Have your instructor evaluate the job.

☐ 9. Disassemble the system.

☐ 10. Return tools and materials to proper storage.

☐ 11. Clean the work area.

Evaluator's Comments: ____

____

____

Objective 11

Job Sheet 2—Wire a Latching Relay or Contactor

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Circuit operates correctly	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Writing Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

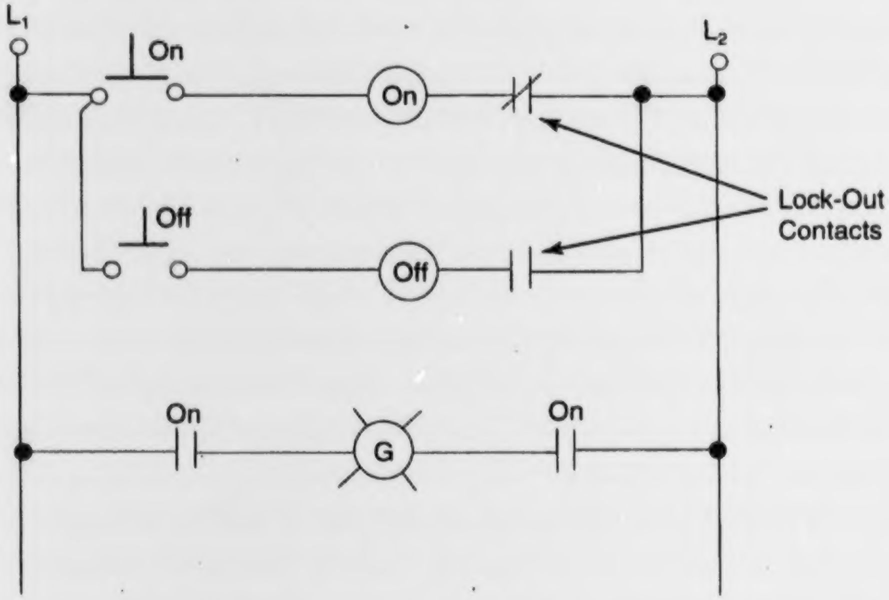
- Pouch tools
- 4-pole latching relay (2 N/O - 2 N/C) (120 volt coils)
- Two N/O push buttons and enclosures
- Pilot light (120 volt) and enclosures
- 10 feet of #14 THHN
- Six #10 x 1″ sheet metal screws
- Mounting board

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Using the following diagram, wire a latching relay to operate a lighting load.


L_1
L_2
On
On
Off
Off
Lock-Out Contacts
On
G
On

☐ 4. Have your instructor evaluate the job.

☐ 5. Disassemble the system.

☐ 6. Return tools and materials to proper storage.

☐ 7. Clean the work area.

Evaluator's Comments: ________________________________

____

____

Objective 12

Job Sheet 3—Wire a Timed "On" Circuit

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	____
• Explanation correct	____
• System operates	____
• Demonstrated good workmanship	____
• Complied to *NEC*	____

Basic Skills

Reading Writing Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

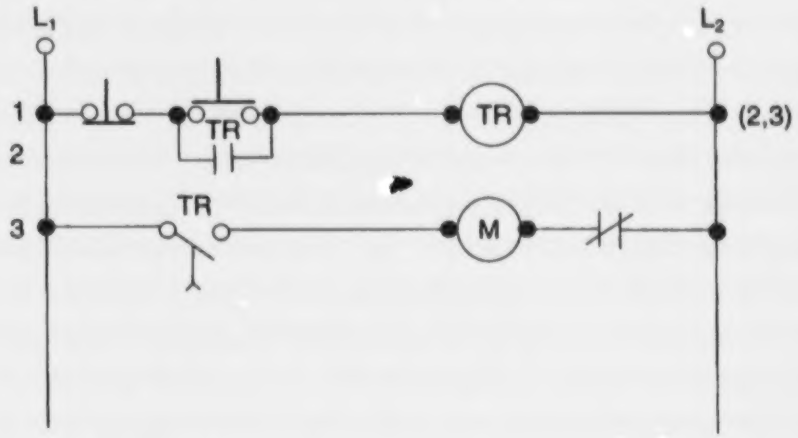
- Pouch tools
- Time delay relay with timed closed contacts (120 volt coil)
- Three-phase motor starter (120 volt coil)
- Start/stop station
- Eight #10 x 1" sheet metal screws
- Mounting board
- 15 feet of #16 THHN

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Using the following diagram, build an "on" delay circuit.



☐ 4. In complete sentences, explain the sequence of operation of the circuit.

____

____

____

____

____

____

☐ 5. Have your instructor approve your explanation.

☐ 6. Build the circuit.

☐ 7. Have your instructor evaluate the job.

☐ 8. Disassemble the system.

☐ 9. Return tools and materials to proper storage.

☐ 10. Clean the work area.

Evaluator's Comments: ____

____

____

Objective 13

Job Sheet 4—Wire a Timed "Off" Circuit

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Explanation correct	______
• System operates correctly	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Writing Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools
- Time delay relay with timed open contacts (120 volt coil)
- General purpose relay (120 volt coil)
- Three-phase motor starter
- Two N/O push buttons with enclosure
- N/C push button with mushroom head and enclosure
- Ten #10 x 1″ sheet metal screws
- Mounting board
- 15 feet of #16 THHN
- 2μF300 volt nonelectrolytic capacitor

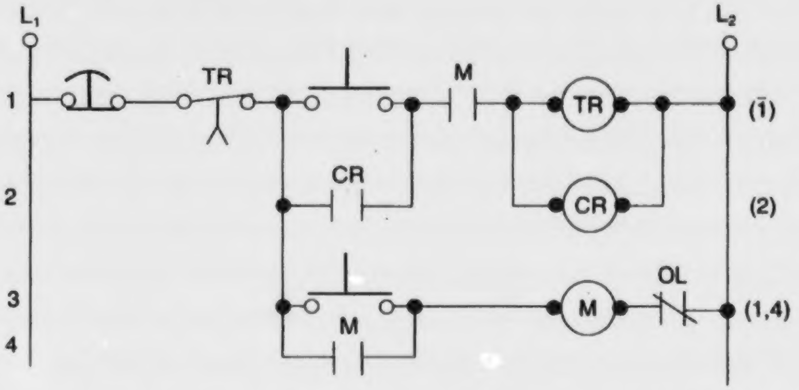
Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Using the following diagram, build an "off" delay circuit.

Note: Any time an off delay is used, an emergency shutdown button must be installed.



Note: In many cases it may be necessary to parallel a 1 to 2 micro-Farad non-electrolytic capacitor with the timing relay. If the circuit tends to restart after the reclosure of contact TR on rung 1, the capacitor will be necessary to hold the contact open longer.

☐ 4. In complete sentences, explain the sequence of operation of the circuit.

☐ 5. Have your instructor approve your explanation.

☐ 6. Build the circuit.

☐ 7. Have your instructor evaluate the job.

☐ 8. Disassemble the system.

☐ 9. Return tools and materials to proper storage.

☐ 10. Clean the work area.

Evaluator's Comments:

Objective 14

Job Sheet 5—Energize Three Starters In a Timed Sequential Order

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Ladder diagram correct	______
• Explanation correct	______
• System operates	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Writing Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools
- Two time delay relays (NOTC) 120 volt coil
- Three 3ϕ starters, 120 volt coils
- N/O push button
- N/C push button
- Three-element control station
- Mounting board
- Twenty #10 x 1″ sheet metal screws
- 20 feet of #16 THHN

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Design and draw a ladder diagram of a circuit to act as follows:

a. Depress start.

1) Starter 1 energizes instantly.

2) 10 second delay, then starter 2 energizes.

3) 10 second delay, then starter 3 energizes.

b. Depress stop—All systems de-energize.

☐ 4. In complete sentences, write a detailed explanation of how your system operates.

☐ 5. Have your instructor evaluate your diagram and explanation.

☐ 6. Build the circuit.

☐ 7. Have your instructor evaluate the job.

☐ 8. Retain circuit for use in Job Sheet 6.

☐ 9. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 15

Job Sheet 6—De-Energize Three Starters in a Timed Sequential Order

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Ladder diagram correct	______
• Explanation correct	______
• Circuit operates correctly	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Writing Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools
- Circuit from Job Sheet 5
- N/O push button
- Three time delay relays (NOTC) 120 volt coil
- Six #10 x 1″ sheet metal screws
- 10 feet of #16 THHN

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Revise the diagram from Job Sheet 5 to act as follows:

- a. Depress start.
  - 1) Starter 1 energizes instantly.
  - 2) 10 second delay, then starter 2 energizes.
  - 3) 10 second delay, then starter 3 energizes.
- b. Depress stop
  - 1) Starter 3 de-energizes instantly.
  - 2) 10 second delay, then starter 2 de-energizes.
  - 3) 10 second delay, then starter 3 de-energizes.
- c. Depress emergency stop—All systems de-energize.

☐ 4. In complete sentences, write a detailed explanation of how your system operates.

☐ 5. Have your instructor evaluate your diagram and explanation.

☐ 6. Build the circuit.

☐ 7. Have your instructor evaluate the job.

☐ 8. Disassemble the system.

☐ 9. Return tools and materials to proper storage.

☐ 10. Clean the work area.

Evaluator's Comments: ______

Objective 16

Job Sheet 7—Build a Ground Fault Indicator Circuit

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Practiced safety rules throughout procedure	______
• Ladder diagram correct	______
• Circuit operates correctly	______
• Demonstrated good workmanship	______
• Complied to *NEC*	______

Basic Skills

Reading Writing Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Pouch tools
- Control transformer 240/120 volt
- Three-phase starter
- Start/stop station
- Two 120 volt pilot lights and 2-element enclosure
- Eight #10 x 1″ sheet metal screws
- 15 feet of #16 TFF
- Mounting board
- 240 volt power source
- Two fuse holders
- Two 6/10 amp fuses

Procedure

☐ 1. Observe safety rules throughout procedure.

☐ 2. Check out proper tools and materials.

☐ 3. Design and draw a ladder diagram of a three-wire control system to operate a three-phase starter. The control circuit should be equipped with a ground fault indicator.

☐ 4. Have your instructor approve your diagram.

☐ 5. Build the circuit.

☐ 6. Have your instructor evaluate the job.

☐ 7. Disassemble the system.

☐ 8. Return tools and materials to proper storage.

☐ 9. Clean the work area.

Evaluator's Comments: ______________________________

____

____

Objective 13

Assignment Sheet 1—Match I/O Devices with Their Functions

Name ______________________ Overall Rating __________

Date ______________________

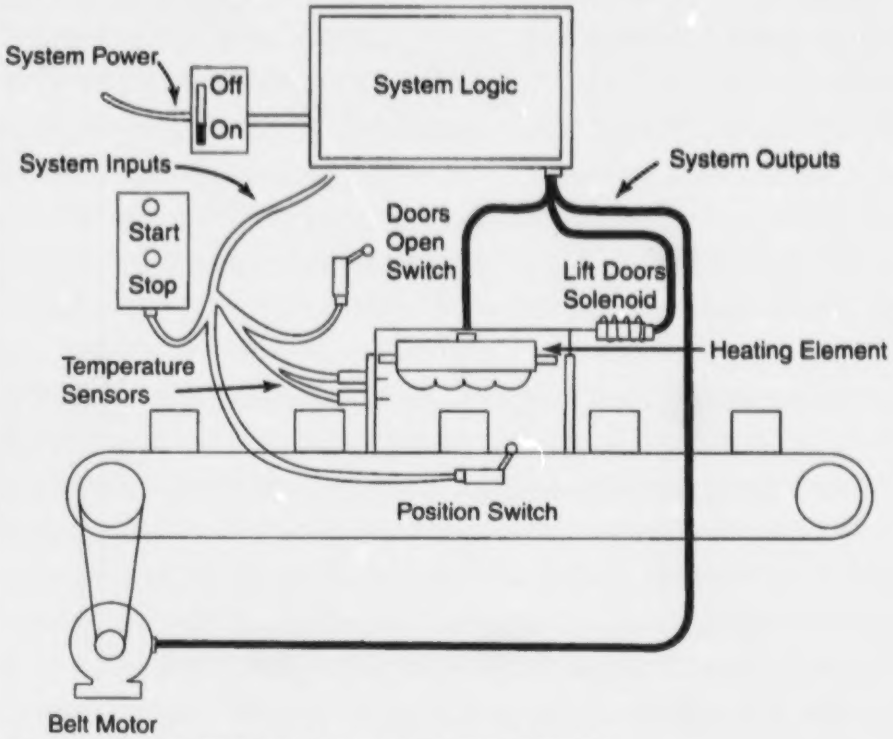
Evaluation Criteria	Rating
• Demonstrated understanding of I/O device functions	______
• Correct answers given	______

Basic Skills

Reading

Directions

Using the pictorial drawing of a PLC managed system, match I/O devices with their correct functions. The above criteria will be used to evaluate your performance.


System Power
Off
On
System Logic
System Inputs
System Outputs
Start
Stop
Doors Open Switch
Lift Doors Solenoid
Heating Element
Temperature Sensors
Position Switch
Belt Motor

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Assignment Sheet 1

1. Doors open switch	3. Start button
2. Position switch	4. Temperature sensor

_____ a. It deactivates, signaling the logic to begin the heating cycle

_____ b. It signals the logic to begin the process and start the belt moving

_____ c. Allows the heat to only reach a certain level

_____ d. Signals the logic that a workpiece is in the oven and to close the doors

723

Objective 14

Assignment Sheet 2—Convert Between Numbering Systems

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Demonstrated ability to convert systems	______
• Correct conversions given	______

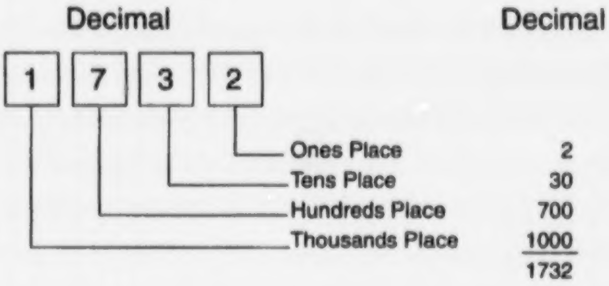
Basic Skills

Directions

Study the following descriptions of the various numbering systems, then complete the indicated conversions. The above criteria will be used to evaluate your performance.

Decimal System

The numbering system your are familiar with is called the decimal system. It uses ten unique characters. Each character represents a power of ten.

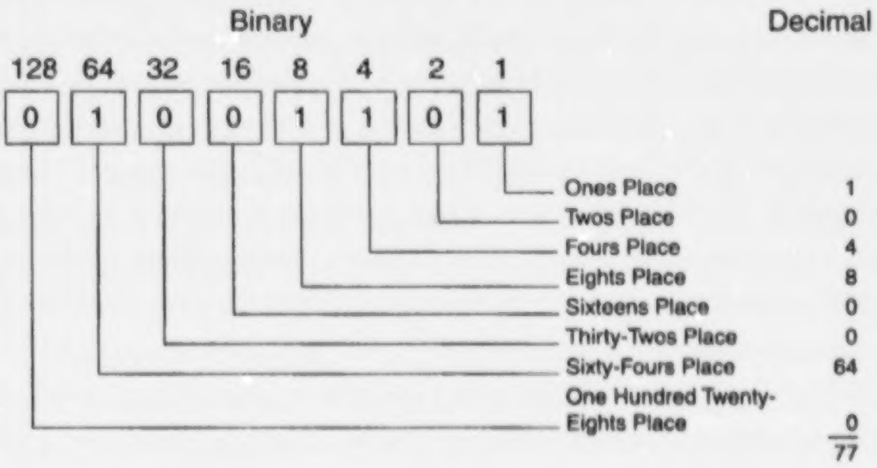

Decimal
Decimal
1
7
3
2
Ones Place
2
Tens Place
30
Hundreds Place
700
Thousands Place
1000
1732

Assignment Sheet 2

Binary System

The on/off status of a switch is easily read by a computer. The binary system is the basis of computer operations. The binary system uses two unique characters (1 and 0). Each character represents a power of two.

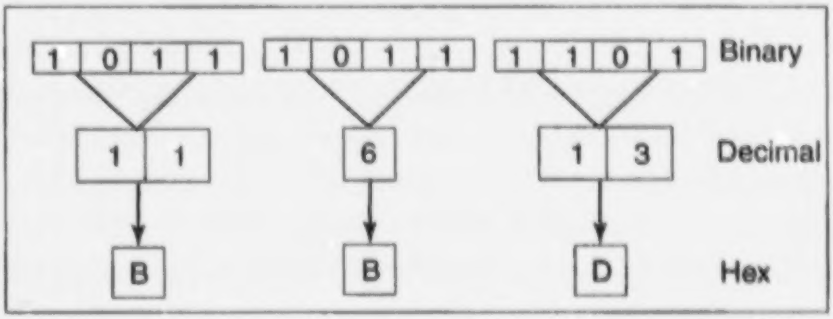
When translating a binary number to a decimal number, include the columns which contain a binary one, and disregard the columns which contain a binary zero.


Binary
Decimal
128 64 32 16 8 4 2 1
0 1 0 0 1 1 0 1
Ones Place 1
Twos Place 0
Fours Place 4
Eights Place 8
Sixteens Place 0
Thirty-Twos Place 0
Sixty-Fours Place 64
One Hundred Twenty-Eights Place 0
77

Hexidecimal System

Note: Since a computer operates in binary, a coding system was developed to allow the decimal numbers on thumbwheels and readouts to be used by a PLC. It is called "Binary Coded Decimal" or "BCD". In the following example, the BCD number shown may be simplified to the hexidecimal B6D.

Hex allows the PLC to display a larger number of binary combinations as a three column readout. The hex system uses sixteen unique characters (O, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F). Letters A through F represent the decimal numbers 10 through 15.



Binary	Decimal	Hexidecimal
0000	0	0
0001	1	1
0010	2	2
0011	3	3
0100	4	4
0101	5	5
0110	6	6
0111	7	7
1000	8	8
1001	9	9
1010	10	A
1011	11	B
1100	12	C
1101	13	D
1110	14	E
1111	15	F

Assignment Sheet 2

Convert the following as indicated

a. Decimal 078 =

____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ BCD

b. Decimal 493 =

____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ BCD

c. Decimal 206 =

____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ BCD

d. Decimal 851 =

____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ BCD

e. 0101-0001-0110 BCD =

____ ____ ____ Decimal

f. 0011-1001-0010 BCD =

____ ____ ____ Decimal

g. 0010-1000-0111 BCD =

____ ____ ____ Decimal

h. 1010-1001-1111 BCD =

____ ____ ____ Hex

i. 0111-1101-1100 BCD =

____ ____ ____ Hex

j. 0110-0101-1011 BCD =

____ ____ ____ Hex

Special Supplement
Suggestions to the Student

All of the scenarios presented in this supplement are real situations. You will be required to apply all of the knowledge you have gained to this point. Many of the problems provided in these scenarios will require some research in solving the design aspect of the problem. Use the resource materials which are available as well as your imagination. **You are encouraged to create your own solutions.** Do not depend on anyone for assistance except your instructor unless you are assigned a partner. Remember, when you begin working in the field you may be required to solve similar problems.

Problems may include bids or a material list. Remember, the electrical market is highly competitive. You must not "gold plate" a job. Your solution should conform to current *NEC* and industry standards. Safety and the customer should always be of the utmost importance.

Scenarios included in this supplement include:

1. Two-wire control applications
2. Timed operation applications
3. Reversing applications
4. Oil field applications
5. Reversing alternative applications
6. Limitation of movement applications
7. Back spin protection applications
8. Hazardous mixing applications
9. Sequential starting applications
10. Sequential shutdown applications

Each of the scenarios listed above will require a technical report as part of the problem solving process. The report should include a detailed explanation of the operation of the circuit and should be referenced to your ladder diagram. In addition, include any other pertinent information such as why a particular NEMA type of enclosure was chosen.

All calculations must also be included in the report. These should include voltage drop calculations, branch circuit sizing, and overcurrent protection.

Suggestions to the Student

When determining the material list, be sure you include all necessary materials such as:

1. Starter (size and type)
2. Overload heaters
3. Disconnect (size and type)
4. Fuses
5. Conduit
6. Connectors and couplings
7. Liquidtight
8. Flex
9. Junction boxes and covers
10. Screws
11. Straps
12. Any other materials not listed above

Scenario 1—Two Wire Control

Name ______________________________ Overall Rating __________

Date ______________________________

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Part I Evaluation

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report. You should cite the *NEC* Article number where applicable.

Evaluation Criteria	Rating
• Circuit Design	30
• Conformity to Code	25
• Workmanship	20
• Time	25
• Technical Report	100

Start Time ______________________ Instructor's Initials ____________

Completion Time ________________ Instructor's Initials ____________

Possible Points		Points Deducted/Reason	Points Earned/Comments
Design	30		
Code	25		
Workmanship	20		
Time	25		
			Total Pts. Earned
Technical Report	100		Total Report Pts. Earned
			Grand Total

Scenario 1

Part 2
Problem

A Trucking Company with an extremely large loading dock has a problem with standing water after every heavy rain. The area where the trucks back in has been excavated to a depth of 5.5 feet below street level. Since this is below the level of the city storm sewer, it is impossible to drain the area with gravity. A plumbing company has installed two lift pumps to force the water uphill to drain it to the sewer.

One pump is 160 feet from the panel, the other is 240 feet from the panel. Both motors are 3/4 HP, 240V, 3ϕ squirrel cage units. It will be necessary to operate the controls by float switches located in sumps.

This job will be done on a cost-plus basis. You will need a complete material list for billing purposes.

Time Limit: ____________

ELECTRICAL PRICING SHEET

JOB

WORK

ESTIMATE NO.

SHEET NO. OF SHEETS

ESTIMATED BY	PRICED BY	EXTENDED BY	CHECKED BY	DATE

	✓	MATERIAL	QUANTITY	MATERIAL PRICE	PER	MATERIAL EXTENSION	LABOR UNIT	PER	LABOR EXTENSION
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									

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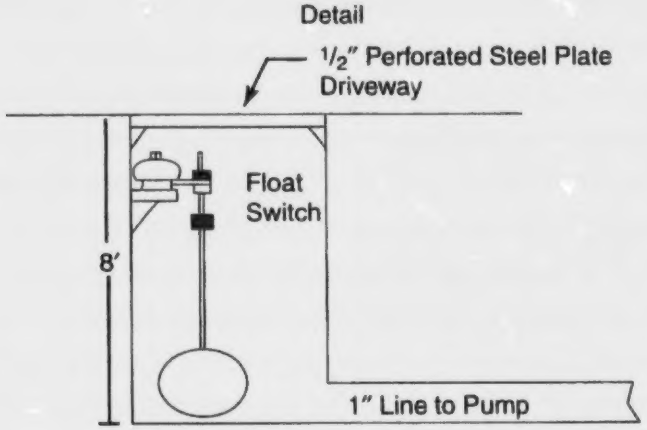
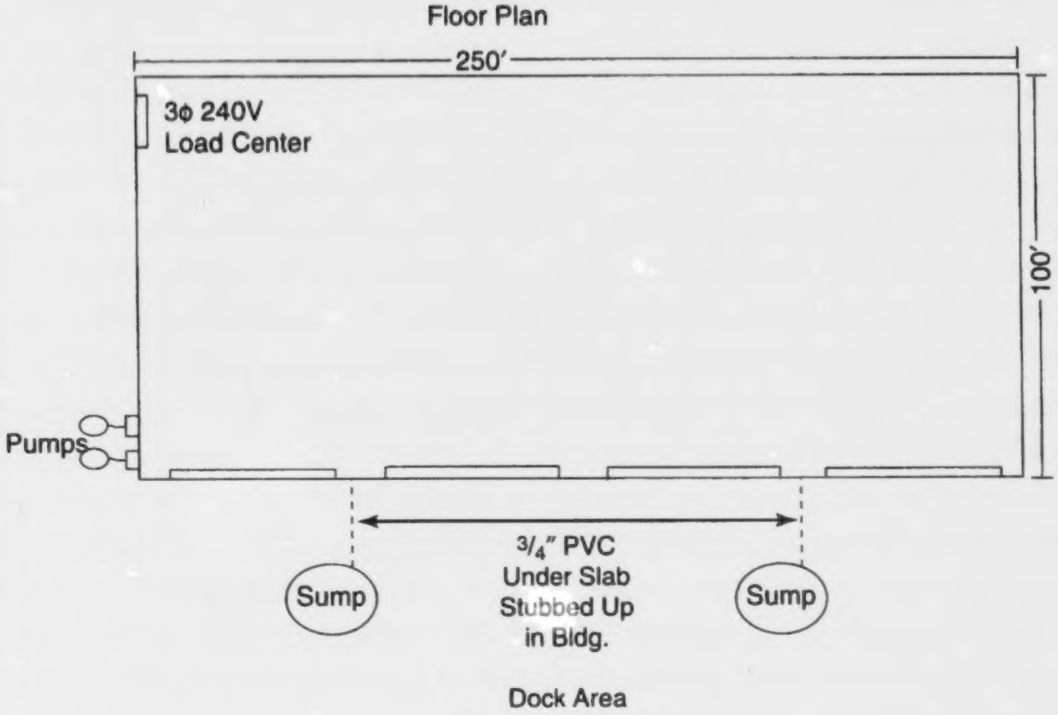
Scenario 1


Detail
$^1/_2$" Perforated Steel Plate
Driveway
Float
Switch
8′
1" Line to Pump


Floor Plan
250′
3ϕ 240V
Load Center
100′
Pumps
$^3/_4$" PVC
Under Slab
Stubbed Up
in Bldg.
Sump
Sump
Dock Area

Scenario 2—Timed Operation

Name ______________________________ Overall Rating __________

Date ______________________________

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Part I Evaluation

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report. You should cite the *NEC* Article number where applicable.

Evaluation Criteria	Rating
• Circuit Design	30
• Conformity to Code	25
• Workmanship	20
• Time	25
• Technical Report	100

Start Time ______________________ Instructor's Initials ___________

Completion Time _________________ Instructor's Initials ___________

Possible Points		Points Deducted/Reason	Points Earned/Comments
Design	30		
Code	25		
Workmanship	20		
Time	25		
			Total Pts. Earned
Technical Report	100		Total Report Pts. Earned
			Grand Total

Scenario 2

Part 2
Problem

A chemical company has contracted your firm to install a control system to operate a mixing pump. The pump must run for one hour, then shut down for one hour. This cycle must continue 24 hours a day. There must also be a means of turning the pump on manually, and a way to turn it off for tank cleaning. The mixing pump is a 7.5 HP, 240 volt, 3ϕ unit. It is located 475 feet from the distribution panel. The chemicals held in the tank are non-corrosive, non-explosive mixtures. The tank is located in the main building. The building is a steel structure.

This will be billed as a cost-plus job. You will be required to make a complete material list and price (your cost) each item.

Time Limit: ____________

ELECTRICAL PRICING SHEET

JOB

WORK

ESTIMATE NO.	
SHEET NO.	OF SHEETS

ESTIMATED BY	PRICED BY	EXTENDED BY	CHECKED BY	DATE

	✓	MATERIAL	QUANTITY	MATERIAL PRICE	PER	MATERIAL EXTENSION	LABOR UNIT	PER	LABOR EXTENSION
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									

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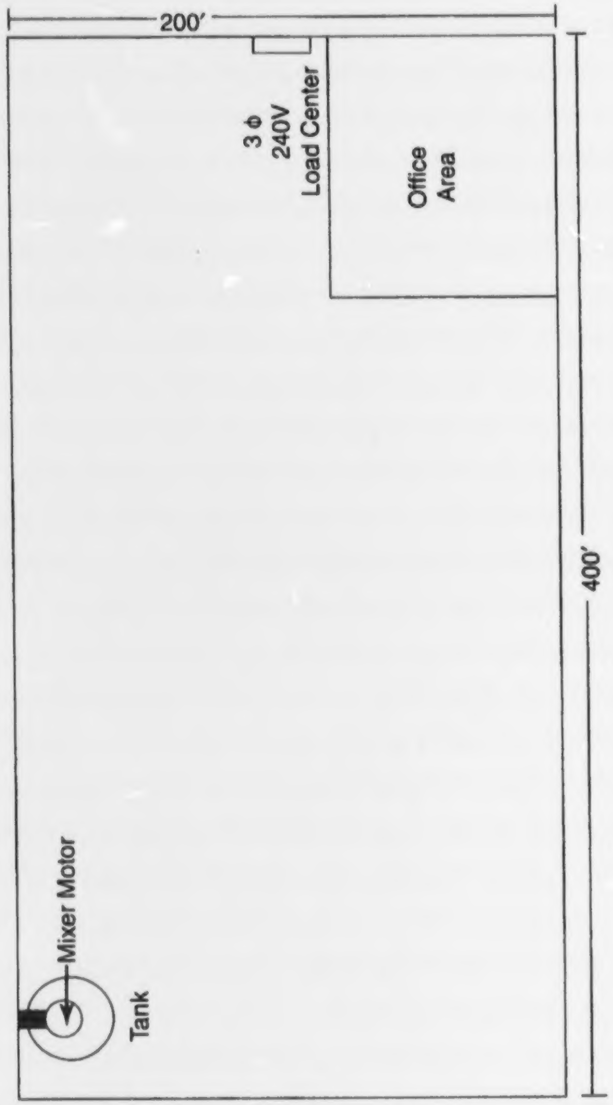
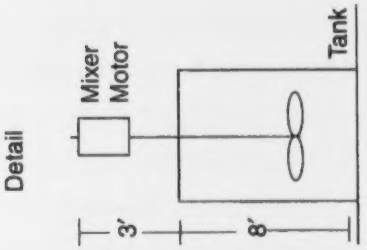
Scenario 2


200′
400′
3 Φ
240V
Load Center
Office
Area
Mixer Motor
Tank


Detail
Mixer
Motor
Tank
3′
8′

Scenario 3—Reversing Applications

Name ______________________ Overall Rating __________

Date ______________________

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Part I Evaluation

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report. You should cite the *NEC* Article number where applicable.

Evaluation Criteria	Rating
• Circuit Design	30
• Conformity to Code	25
• Workmanship	20
• Time	25
• Technical Report	100

Start Time ______________ Instructor's Initials __________

Completion Time ______________ Instructor's Initials __________

Possible Points		Points Deducted/Reason	Points Earned/Comments
Design	30		
Code	25		
Workmanship	20		
Time	25		
			Total Pts. Earned
Technical Report	100		Total Report Pts. Earned
			Grand Total

Scenario 3

Part 2 Problem

A call has just come in to the dispatcher of your electrical contracting firm. The customer has requested that you install a control to reverse the rotation of a large fan located in the gable end of his automotive repair shop. It will be used to exhaust fumes, and to bring in fresh air. The customer wants two control stations, one located directly below the fan, the other in the office. The fan motor is a 3ϕ, 3 HP, 208 volt unit. The owner has requested that you prepare a proposed cost figure before doing the job. He has furnished you with a rough drawing of his building for bidding purposes. The building is a wooden structure with no ceilings in the shop area, and the interior walls of the shop are covered with 4$^{1}/_{2}$" plywood. The fan is 17 feet above the floor.

Time Limit: ______________

ELECTRICAL PRICING SHEET

JOB

WORK

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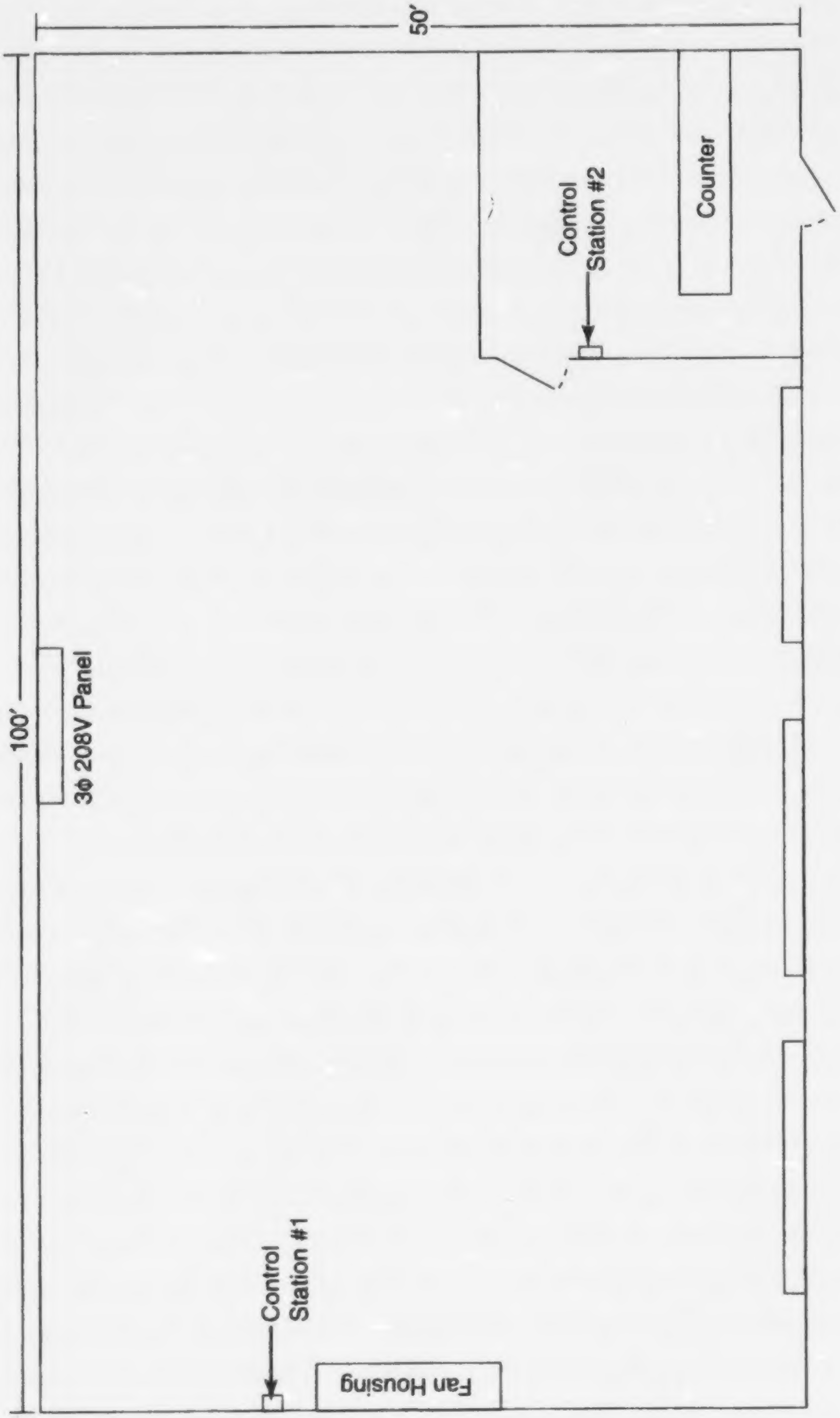
Scenario 3


50′
100′
Counter
Control Station #2
3ϕ 208V Panel
Control Station #1
Fan Housing

Scenario 4—Oil Field Applications

Name ______________________ Overall Rating __________

Date ______________________

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Part I Evaluation

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report. You should cite the *NEC* Article number where applicable.

Evaluation Criteria	Rating
• Circuit Design	30
• Conformity to Code	25
• Workmanship	20
• Time	25
• Technical Report	100

Start Time ______________ Instructor's Initials __________

Completion Time ______________ Instructor's Initials __________

Possible Points		Points Deducted/Reason	Points Earned/Comments
Design	30		
Code	25		
Workmanship	20		
Time	25		
			Total Pts. Earned
Technical Report	100		Total Report Pts. Earned
			Grand Total

Scenario 4

Part 2
Problem

Wildcat Oil Company, a steady customer, has requested that you install a 480 volt, 5 HP, 3ϕ motor on a small pumping unit. This job will include the complete rebuilding and rewiring of a Cutler-Hammer pump panel. Remember, when wiring a pump jack it is necessary to ground your equipment at the wellhead to eliminate any difference of potential. The job will not require a material list, however, your technical report must list the overload and overcurrent protection requirements.

Time Limit: ____________

Scenario 5—Reversing Alternatives

Name ______________________ Overall Rating __________

Date ______________________

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Part I Evaluation

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report. You should cite the *NEC* Article number where applicable.

Evaluation Criteria	Rating
• Circuit Design	30
• Conformity to Code	25
• Workmanship	20
• Time	25
• Technical Report	100

Start Time ______________ Instructor's Initials __________

Completion Time ______________ Instructor's Initials __________

Possible Points		Points Deducted/Reason	Points Earned/Comments
Design	30		
Code	25		
Workmanship	20		
Time	25		
			Total Pts. Earned
Technical Report	100		Total Report Pts. Earned
			Grand Total

Scenario 5

Part 2
Problem

A meat processing plant has an overhead chain conveyor used to transport halves of beef from the cutting room to the cooler. Occasionally it is necessary to run the conveyor in reverse. Since this happens only a few times a month, the owner does not want to go to the expense of installing a reversing starter. A drum switch would be the perfect alternative. The conveyor already has a motor starter and a start/stop station in place. Your job is to install the drum switch to reverse the motor. It will be necessary to check the overcurrent and overload protective devices to be sure that they are of the proper size. This is a cost-plus job, so you must list all materials used as well as hours on the job.

Time Limit: ____________

ELECTRICAL PRICING SHEET

JOB

WORK

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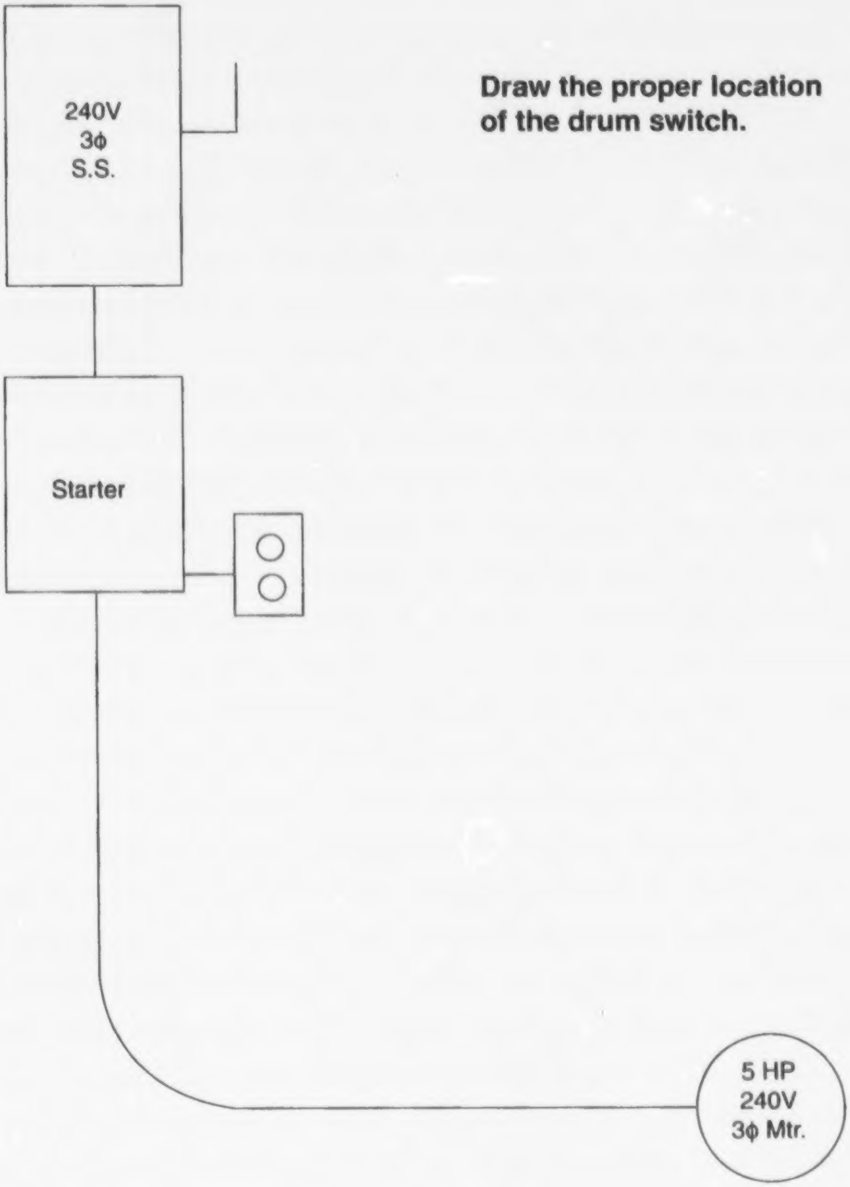
Scenario 5


240V
3ϕ
S.S.
Starter
5 HP
240V
3ϕ Mtr.

Draw the proper location of the drum switch.

Scenario 6—Limitation of Movement

Name ______________________ Overall Rating __________

Date ______________________

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Part I Evaluation

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report. You should cite the *NEC* Article number where applicable.

Evaluation Criteria	Rating
• Circuit Design	30
• Conformity to Code	25
• Workmanship	20
• Time	25
• Technical Report	100

Start Time ______________ Instructor's Initials __________

Completion Time ______________ Instructor's Initials __________

Possible Points		Points Deducted/Reason	Points Earned/Comments
Design	30		
Code	25		
Workmanship	20		
Time	25		
			Total Pts. Earned
Technical Report	100		Total Report Pts. Earned
			Grand Total

Scenario 6

Part 2
Problem

A welding shop has just gotten a contract to build pressure vessels. Since these items are so large, it has become necessary to cut a larger door in the side of their metal building. The door is so large that it is impossible to use an overhead door. The new door will run on a track and slide along the wall. Your job is to install the electrical power and control circuits for the new door. You will be competing for the job with several other electrical contractors. You must visit the shop and make a sketch of the building, panel location, and door location. This sketch will be used for bidding purposes.

You must install limit switches to limit the travel of the door when opening or closing. Remember, when the door is fully open and against the limit switch, you must be able to close it or vice versa.

Time Limit: ____________

ELECTRICAL PRICING SHEET

JOB
WORK

ESTIMATE NO.	
SHEET NO.	OF SHEETS

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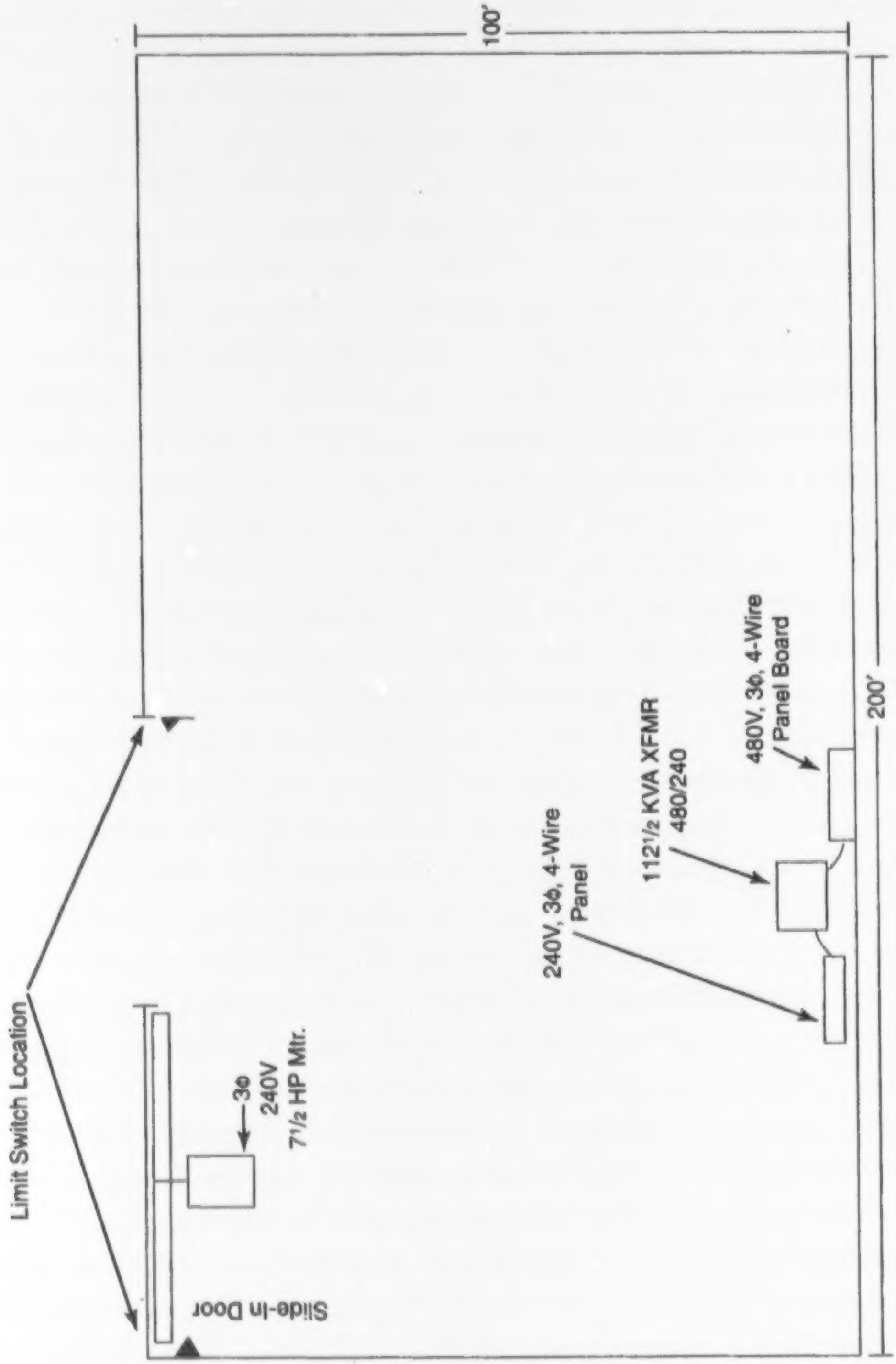
Scenario 6


100'
200'
Limit Switch Location
Slide-In Door
3ϕ
240V
7½ HP Mtr.
240V, 3ϕ, 4-Wire
Panel
112½ KVA XFMR
480/240
480V, 3ϕ, 4-Wire
Panel Board

Scenario 7—Back Spin Protection

Name ______________________ Overall Rating __________

Date ______________________

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Part I Evaluation

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report. You should cite the *NEC* Article number where applicable.

Evaluation Criteria	Rating
• Circuit Design	30
• Conformity to Code	25
• Workmanship	20
• Time	25
• Technical Report	100

Start Time ______________ Instructor's Initials __________

Completion Time ______________ Instructor's Initials __________

Possible Points		Points Deducted/Reason	Points Earned/Comments
Design	30		
Code	25		
Workmanship	20		
Time	25		
			Total Pts. Earned
Technical Report	100		Total Report Pts. Earned
			Grand Total

Scenario 7

Part 2
Problem

You have been contacted by the city water department. They have come across a problem that is typical of submerged pumps in deep wells. When the water pressure in the tank is at a point that allows the "down hole" pump to shut down, the water begins to flow back down the hole, forcing the pump's impeller to spin in reverse. If the pressure drops to a point that makes the pump start while this "back spin" is in progress, the pump motor can be severely damaged.

Your job is to correct this problem using your knowledge of motor controls and time delay systems. The pump motor is a 100 HP, 480 volt, 3-phase unit. Upon arrival at the job site, you discover that the motor starter is too small. The director of the water department approves a work order to change the starter while the pump is out of operation.

The conductors feeding the starter and the motor are of the proper size. The existing controls consist of a Murphy switch at the top of the tank to shut the pump down, and a Murphy switch at the bottom of the tank to start the pump. (See attached drawings.)

You will be competing with several contractors for the job, so a bid will be necessary.

Time Limit: ____________

ELECTRICAL PRICING SHEET

JOB

WORK

ESTIMATE NO.

SHEET NO. OF SHEETS

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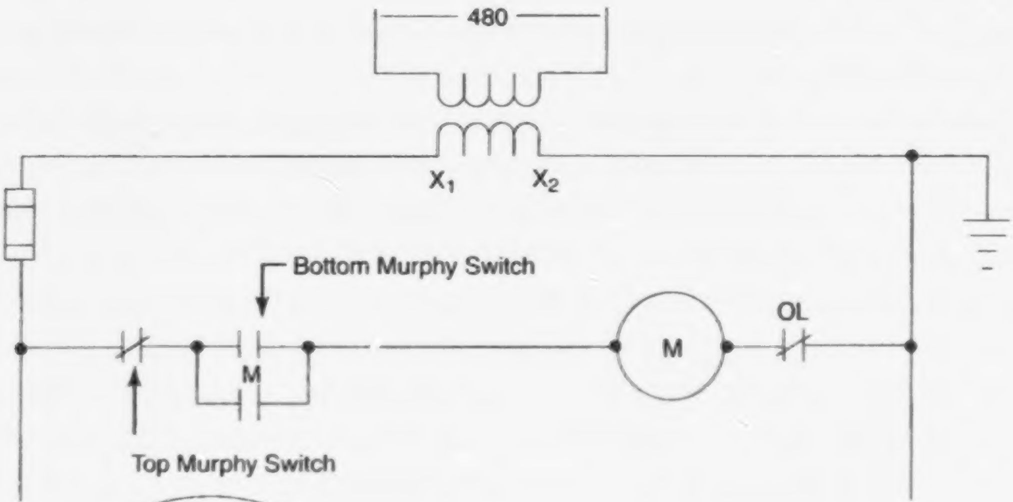
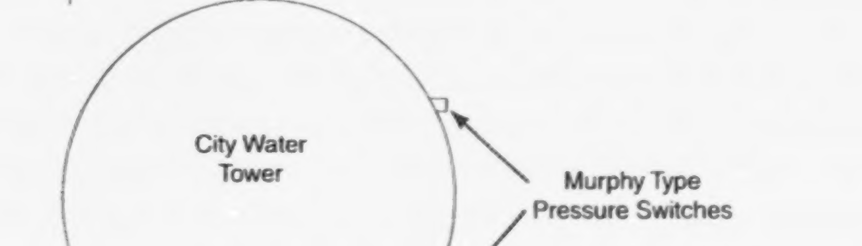
Scenario 7

Existing Controls


480
X_1
X_2
Bottom Murphy Switch
OL
M
M
Top Murphy Switch


City Water Tower
Murphy Type Pressure Switches
Control Building
100 HP Submerged Pump

Scenario 8—Hazardous Mixing

Name ______________________ Overall Rating __________

Date ______________________

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Part I Evaluation

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report. You should cite the *NEC* Article number where applicable.

Evaluation Criteria	**Rating**
• Circuit Design	30
• Conformity to Code	25
• Workmanship	20
• Time	25
• Technical Report	100

Start Time ______________ Instructor's Initials __________

Completion Time ______________ Instructor's Initials __________

Possible Points		**Points Deducted/Reason**	**Points Earned/Comments**
Design	30		
Code	25		
Workmanship	20		
Time	25		
			Total Pts. Earned
Technical Report	100		Total Report Pts. Earned
			Grand Total

Scenario 8

Part 2
Problem

A chemical tank farm has requested you to design and build a delay system for its 3-inch main pump.

The pump is used to load trucks (in clockwise rotation), and to unload trucks (in counter-clockwise rotation). In order to avoid any "back-spin" damage to the motor, you have been asked to design and build a system to delay the start of the motor in either direction after the stop button has been depressed.

The existing pump and controls are:

2 forward/reverse/stop stations
1 3-phase reversing Square D starter
You must also add a pilot light to indicate that the system is running.

Include a complete material list of the necessary items to complete the job.

Time Limit: ____________

ELECTRICAL PRICING SHEET

JOB ____________________

WORK ____________________

ESTIMATE NO.

SHEET NO. ____ OF SHEETS ____

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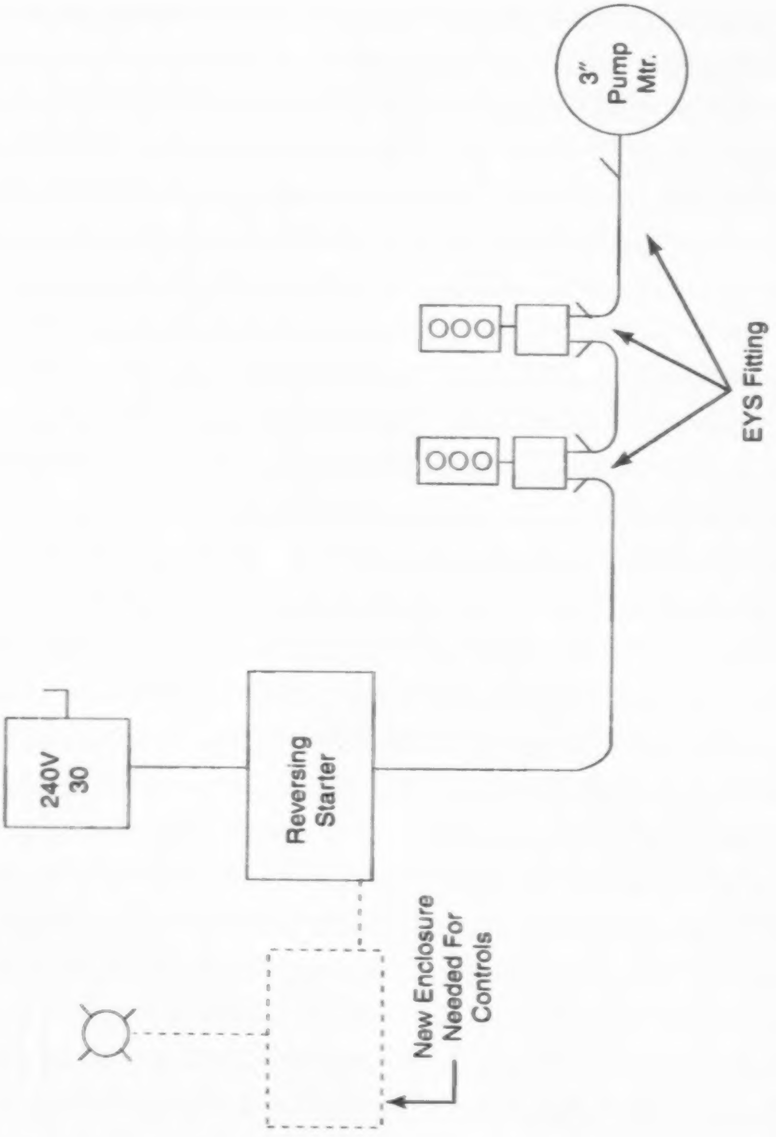
Scenario 8

One Line Diagram


240V
30
Reversing Starter
3"
Pump
Mtr.
EYS Fitting
New Enclosure Needed For Controls

Scenario 9—Sequential Starting

Name ______________________ Overall Rating __________

Date ______________________

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Part I Evaluation

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report. You should cite the *NEC* Article number where applicable.

Evaluation Criteria	Rating
• Circuit Design	30
• Conformity to Code	25
• Workmanship	20
• Time	25
• Technical Report	100

Start Time ______________ Instructor's Initials __________

Completion Time ______________ Instructor's Initials __________

Possible Points		Points Deducted/Reason	Points Earned/Comments
Design	30		
Code	25		
Workmanship	20		
Time	25		
			Total Pts. Earned
Technical Report	100		Total Report Pts. Earned
			Grand Total

Scenario 9

Part 2
Problem

A small aluminum processing company has asked you to install a start-up system in their plant that will allow for an orderly start-up of all equipment in a timed sequential order. As an electrician, you welcome the opportunity for such a challenge. There are seven pieces of equipment that must be included in the start-up.

1. Feed conveyor
2. Shaker #1
3. Grinder
4. Shaker #2
5. Process conveyor #1
6. Process conveyor #2
7. Waste conveyor

Upon actuation of the start button, the feed conveyor will immediately start. A red light will come on to warn all personnel.

One minute later, Shakers #1 and #2 will start.

Forty seconds later, the grinder will start.

One minute later, the process conveyors will start.

Thirty seconds later, the waste conveyor will start.

When the stop button is depressed, all systems will stop. When all systems have ceased to operate, an alarm will sound for fifteen seconds.

Please design a ladder diagram of your control system and submit it with your written report to your instructor for approval before constructing the control system.

Time Limit: ____________

Scenario 10—Sequential Shutdown

Name ______________________________ Overall Rating __________

Date ______________________________

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Part I Evaluation

It is important that your drawing and written reports are of the highest quality. These items will be returned to you for inclusion in a portfolio upon graduation. All calculations must be included in the report. You should cite the *NEC* Article number where applicable.

Evaluation Criteria	Rating
• Circuit Design	30
• Conformity to Code	25
• Workmanship	20
• Time	25
• Technical Report	100

Start Time ____________________ Instructor's Initials ____________

Completion Time ________________ Instructor's Initials ____________

Possible Points		Points Deducted/Reason	Points Earned/Comments
Design	30		
Code	25		
Workmanship	20		
Time	25		
			Total Pts. Earned
Technical Report	100		Total Report Pts. Earned
			Grand Total

Scenario 10

Part 2
Problem

In Scenario 9 you designed and built a system for a timed sequential start-up of an aluminum processing plant. In almost all cases, if a timed sequential start-up is required, a timed sequential shut-down is also necessary. Consider the following:

DEPRESS START

1. Waste conveyors start—30 second delay
2. Process conveyor #2 starts—30 second delay
3. Process conveyor #1 starts—30 second delay
4. Shaker #2 starts—1 minute delay
5. Grinder starts—1 minute delay
6. Shaker #1 starts—45 second delay
7. Feed conveyor starts

DEPRESS STOP

1. Red pilot light energizes and feed conveyors stop—1 minute delay
2. Shakers #1 and #2 shut down—40 second delay
3. Grinder shuts down—1 minute delay
4. Process conveyors shut down—30 second delay
5. Waste conveyors shut down and alarm sounds for 15 seconds

Please complete a ladder diagram of your system with your written explanation and submit these to your instructor for approval before building the system.

Time Limit: ____________

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